Coeur d'Alene Lake and River (17010303) Sub-basin Assessment and Proposed Total Maximum Daily Loads

Idaho Department
of Health and Welfare
Division of
Environmental Quality

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Table of Contents

1. Executive Summary of the Coeur d'Alene Lake and River (17010303) Sub-basin Assessment and Proposed Total Maximum Daily Loads

The Coeur d'Alene Lake and River Sub-basin consists of the Coeur d'Alene Lake and River and those water bodies which drain directly to the river and the lake. The sub-basin contains 30 water bodies which have been listed as water quality limited on the Section 303(d) Clean Water Act lists. The beneficial uses of these streams and lakes are generally cold water biota and primary contact recreation although the river and the lake and a few additional lakes have more extensive beneficial uses designated in the Idaho water quality standards. These water bodies are listed for one or more of the following pollutants: bacteria, habitat alteration, nutrients, sediment, dissolved oxygen, oil and grease, pH and temperature.

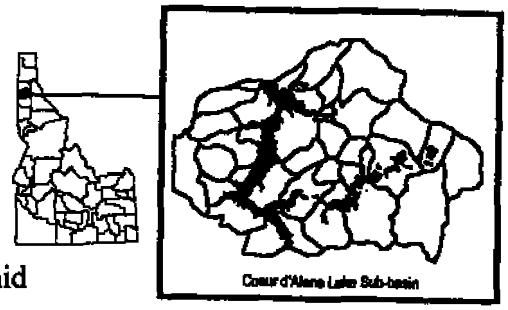
The existing data for each of the water bodies is reviewed in the sub-basin assessment. Where those data were inconclusive, additional data on bacteria, nutrients and temperature were collected during the summer months of 1999. The sediment generation of the watersheds of those water bodies listed as limited by excess sedimentation was modeled. Following analysis of the data and the modeling results, eighteen water bodies in the sub-basin were verified to be water quality limited by at least one pollutant: eleven for temperature, eight for sediment and one for bacteria. Fernan Lake was not found limited, but nutrient levels are sufficiently high to warrant an advisory total maximum daily load (TMDL). The temperature TMDLs have been deferred by the state until state temperature criteria are fully examined and if necessary adjusted. The sediment limitations in the upper two segments of the Coeur d'Alene River can practically be addressed by sediment TMDLs for the North and South Forks of the Coeur d'Alene River. Lake Creek, which is sediment limited, is wholly on the Coeur d'Alene Reservation and the lead agency responsible is EPA.

Proposed total maximum daily loads for sediment were developed for Wolf Lodge Creek including its tributary Cedar Creek, Cougar Creek, Mica Creek and Latour Creek including its tributaries Baldy and Larch Creeks. A TMDL for bacteria was developed for Mica Creek.

A thirty-day public comment period was provided from November 18 through December 17, 1999. Three letters of comment containing twenty-three substantive comments were received by the close of the comment period. The draft TMDLs were revised based on the comment recieved. A responsiveness summary discusses all the comments received.

2. COEUR D'ALENE LAKE AND RIVER SUB-BASIN (17010303) ASSESSMENT

2.0 Coeur d'Alene Lake and River Sub-basin Water Quality at a Glance



Water Quality at a Glance:

Hydrologic Unit Code..........................	17010303
Water Quality Limited Segments..........	Coeur d'Alene Lake and River with several tributaries
Beneficial Uses Affected.......................	Cold Water Biota, Salmonid Spawning, Recreation
Pollutants of Concern...........................	Sediment, temperature
Known Land Uses.................................	Forestry, agriculture, urban

2.0.1 Prologue:

The impacts of the trace (heavy) metals cadmium, lead and zinc have been addressed in assessments of the Coeur d'Alene River and the Coeur d'Alene Lake Plan (IDEQ, 1996a; IDEQ, 1998a). Total maximum daily load documents have been developed for these pollutants (IDEQ, 1998b; IDEQ, 1998c). This sub-basin assessment addresses the non-metallic pollutants of concern. For background on the lake and the river the reader is referred to the documents cited.

2.1. Characterization of the Watershed

The Coeur d'Alene Lake and River sub-basin (17010303) includes Coeur d'Alene Lake and the Coeur d'Alene River[1] and the tributaries to these two water bodies (figure 1). The Coeur d'Alene River flows from the confluence of the North and South Forks of the Coeur d'Alene Rivers near Enaville, Idaho westward to its discharge to the Lake Coeur d'Alene near Harrison, Idaho (Figure 1). The City of Coeur d'Alene is located at the northern end of the lake. The Spokane River flows from the lake outlet into the State of Washington.

2.1.1. Physical and Biological Characteristics

The physical and biological characteristics of the sub-basin are described in the following sections on climate, hydrology, landform, geology and soils, vegetation, aquatic fauna and cultural impacts.

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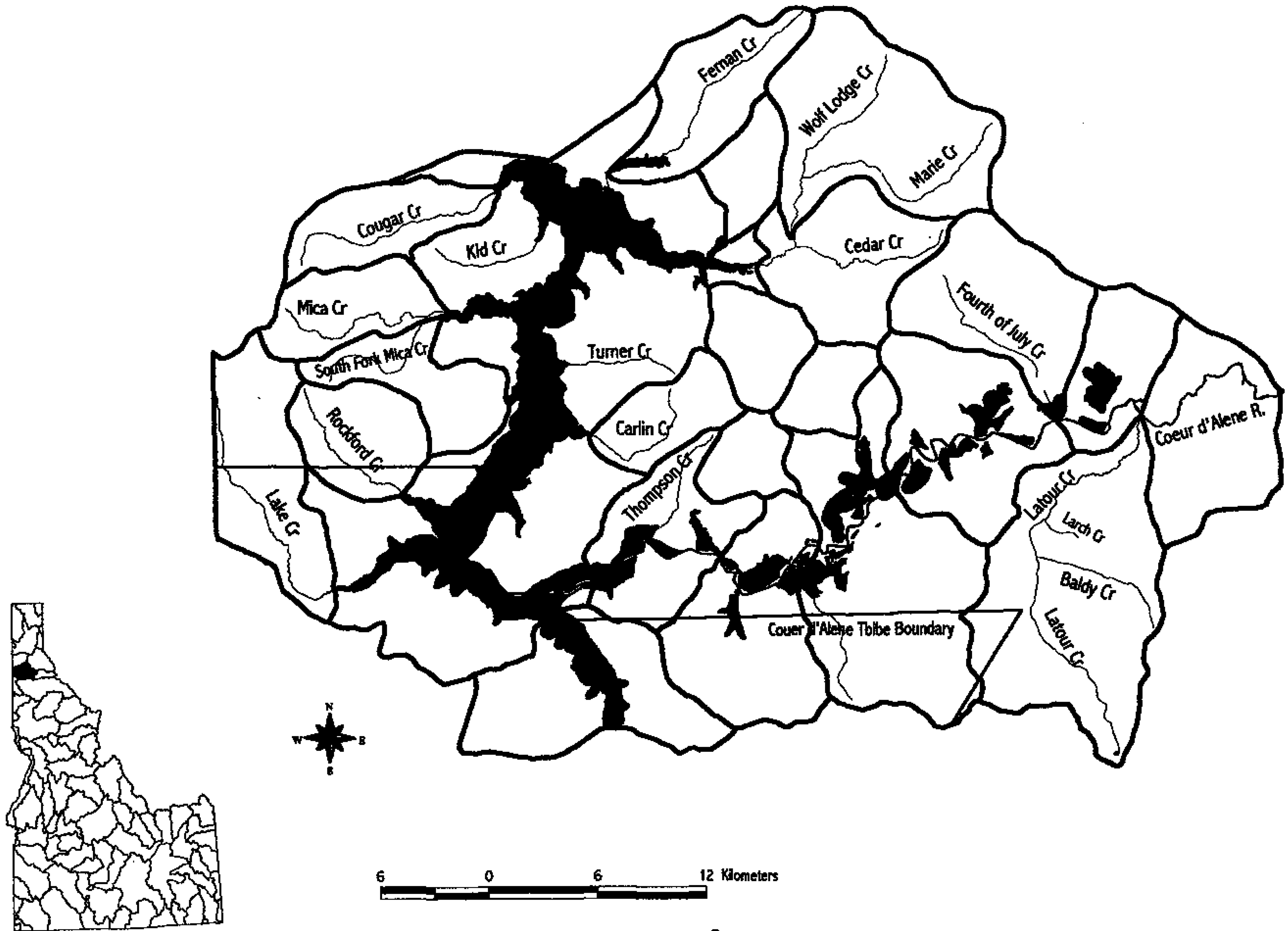
[1] The Coeur d'Alene River above the South Fork Coeur d'Alene River was renamed the North Fork Coeur d'Alene River in 1991. (U.S. Board of Geographic Names, 1991.)

Figure 1. Coeur d'Alene Lake and River Sub-basin HUC 17010303



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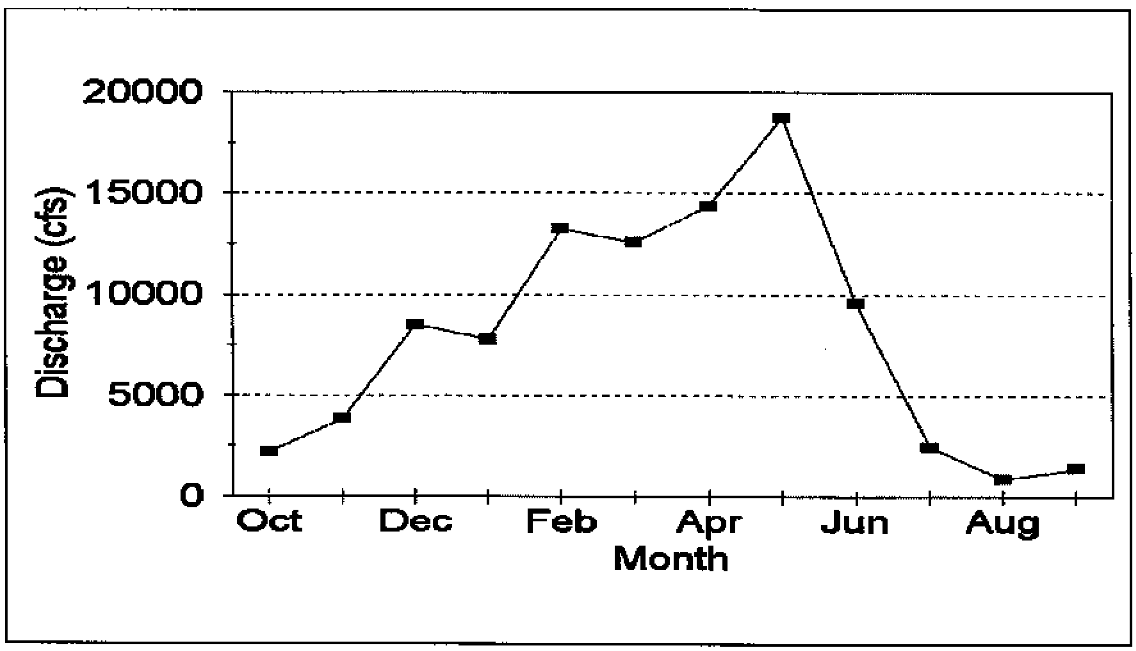
2.1.1.1 Climate

The Coeur d'Alene Lake sub-basin is located in the Northern Rocky Mountain physiographic region to the west of the Bitterroot Mountains. Local climates are influenced by both pacific maritime air masses from the west as well as continental air masses from Canada to the north. The annual weather cycle generally consists of cool to warm summers with cold and wet winters. The relative warmth of summers or winters depends on the dominance of Pacific or continental air masses. Precipitation is most generous in the winter months. Precipitation takes the form of rain generally below 3,000 feet of elevation, while it is in the form of snow above 4,500 feet. The transitional zone between 3,000 and 4,500 feet holds a transient snow pack, which is subject to rapid melt when wet Pacific air masses predominate. The result of these snow melt events are high discharge rain on snow events.

2.1.1.2. Hydrology

The discharge hydrograph of the Spokane River near Post Falls Idaho and immediately downstream of the lake outlet is provided in Figure 2. The discharge of the streams of the sub-basin is dominated by the spring snow melt. The streams draining the Coeur d'Alene and St. Joe Mountains have watersheds predominantly in the elevation range (3,000 - 4,500 feet) subject to winter "rain on snow" discharge events. The relative low elevation of the watersheds causes earlier maximum discharge (mid-March), than from the majority of the watersheds of the North and South Forks of the Coeur d'Alene River. The immediate watersheds of the river and the lake are 34.8% of the total watershed. For this reason the river and the lakes' stage are little affected by the discharge of these streams.

Figure 2: Mean Monthly Discharge of the Post Falls Station 1995-1999.



2.1.1.3 Land forms, Geology and Soils

The Coeur d'Alene River flows through a generally broad floodplain ranging from a quarter to one and three-quarters miles in width. The river and its floodplain are bound on the north by the Coeur d'Alene Mountains and on the south by the St. Joe Mountains. Coeur d'Alene Lake is a submerged river valley impounded initially by the outwash of the Pleistocene Missoulian floods. The lake has been augmented by the Post Fall Dam. Tributaries to the river and the eastern shore of the lake flow from the Coeur d'Alene and St. Joe Mountains. Tributaries to the lake from the west flow either from the Palouse Hills or from the most southerly mountains of the Selkirk Range.

Eleven lakes and numerous wetlands are located laterally to the river below Rose Lake. The lakes vary in size, while the wetlands surrounding them are extensive. The lakes and wetlands are expressions of the high water table of the lower river valley. The lakes are hydrologically connected to the river by surface channels in all but three cases where the connection is through the valley aquifer. Large wetlands are found in the valley above Rose Lake, notably in the area of Cataldo Flats.

The Coeur d'Alene and St. Joe Mountains are composed primarily of Belt Supergroup meta-sedimentary rocks. This geology weathers to predominantly silt size particles with rounded cobbles as the primary transitional material found in the higher gradient streams. The Selkirk Range, from which streams flowing from the northwest drain to the lake, is a granitic formation. These granite substrates weather to sand. The predominant bedload of these streams is sand. The surface soils of the Palouse Hills are largely composed of wind blown silt. The soil is underlain by Columbia River basalt. The basalt is found at the surface near the lake shore. The division between granitic sands of the Selkirk Range and the silts of the Palouse Hills occurs at the northern end of the Lake Creek watershed.

Tributaries to the river and lake flowing from the mountains are high gradient streams channels (Rosgen B), until they reach the valley bottoms. As these streams enter the valley of the river or the lake, an abrupt transition to low gradient (Rosgen C) channels occurs in their final half mile in the case of the river and final few miles in the case of tributaries to the lake. Streams flowing from the Palouse Hills have lower gradients near their headwaters, but have steep channels over basalt deposits as these streams approach the lake.

2.1.1.4. Vegetation

The predominant vegetation of the Coeur d'Alene, St. Joe and Selkirk Mountains which comprise 80% of the sub-basin is mixed coniferous forest. Dominant conifers are pines, true fir, Douglas fir, tamarack and red ceder. Cottonwood, aspen and alder are the predominant deciduous species. The Palouse Highlands have grasslands as well as wooded areas. These areas were likely maintained by fire as grasslands prior to European settlement. Grasslands and wooded areas would have expanded and contracted dependent on the fire cycle which was controlled by the indigenous people. Valley bottoms with little slope are currently grasslands. Vegetation along the Coeur d'Alene River has been diminished by bank erosion and the influence of fluvially deposited metals contaminated sediments. The metals bind phosphate making it less available for plant nutrition. The result is a diminished vegetative cover in some areas. For additional information on the vegetation of the Coeur d'Alene Basin refer to the Coeur d'Alene Lake Management Plan (IDEQ, 1996a).

2.1.1.5. Aquatic Fauna

The native trouts of the sub-basin's streams are cutthroat trout and bull trout. Sculpin, shiners and bullhead catfish are also indigenous. The tailed frog, giant salamander and turtles completed the list of indigenous vertebrate species. The fish fauna of the lake and the river have been greatly altered by the introduction of several trouts, salmon and warm water species. A detailed discussion of the current fishery of Coeur d'Alene Lake and River is available in the Coeur d'Alene Lake Management Plan (IDEQ, 1996a). Although the lake and river have highly altered aquatic fauna due to introductions, headwater streams retain native species with the addition of rainbow and brook trout and the loss of bull trout. Although fish composition appears stable in the headwaters, fish abundance is generally believed to be reduced from historic levels reported as the area was settled. Fish abundance in Coeur d'Alene Lake and River as well as the lateral lakes is high (IDEQ, 1996a).

2.1.2 Cultural Impacts:

The watersheds of the Coeur d'Alene and St. Joe Mountains which drain to the river and the lake are managed primarily for timber production and dispersed recreation. Timber management has been moderately intense with large clear-cut areas and dense road development. Some watersheds as Wolf Lodge and Cedar Creeks have had intense forest management and road development. Land management in this area is primarily by the U.S. Forest Service. Watersheds of the southern Selkirk mountains are also managed primarily for timber production. These tracts are in private and industry ownership. Some forested watersheds on either side of the lake were logged using railroad systems. Near the population centers of Coeur d'Alene, Harrison and the intervening east lake shore, timber management has been less intense to protect scenic values.

From the Lake Creek watershed south in the Palouse Hills region and on Harrison Flats east of the lake, agriculture is the major land use. The Palouse area and Harrison Flats supported wheat production over most of the history of cultivation. In recent years blue grass seed production has replaced some wheat production. Substantial farm land acreage has been placed in the Conservation Reserve Program.

The main population center in the sub-basin is the City of Coeur d'Alene at the north end of the lake. In some nearby watersheds residential development is prevalent. Fernan and Cougar Creeks are examples of watersheds which have residential development. Residences exist in strips along the east and west shore of the lake more or less continuously. Many of these residences are summer cabins but many have become year around residences in recent years. Additional population centers include Harrison, Worley, Plummer, Rose Lake and Cataldo. These towns have populations less than 300. For additional information on the land use and demographics of the Coeur d'Alene Basin refer to the Coeur d'Alene Lake Management Plan (IDEQ, 1996a).

2.2. Regulatory Requirements

The regulatory requirements for the water bodies of the sub-basin are summarized by listing the segments of concern, the assigned beneficial uses and the water quality standards supportive of those uses.

2.2.1. Segments of Concern

The stream segments listed in the 1998 Section 303(d) Clean Water Act List for non-metallic pollutants in sub-basin 17010303 are provided in Table 1.

Table 1: List of 1998 Section 303(d) Clean Water Act listed water bodies.

Water body Name	HUC Number	Boundaries	Pollutant(s)
Cd'A River	17010303 4021	SF Cd'A R to French Gulch	Habitat alteration, pH and sediment
Cd'A River	17010303 4018	French Gulch to Skeel Gulch	Habitat alteration, pH and sediment
Cd'A River	17010303 4022	Skeel Gulch to Latour Creek	Habitat alteration, pH and sediment
Cd'A River	17010303 4019	Latour Creek to Fourth of July Creek	Habitat alteration, pH and sediment
Cd'A River	17010303 4017	Fourth of July Creek to Fortier Creek	Habitat alteration, pH and sediment
Cd'A River	17010303 4016	Fortier Creek to Robinson Creek	Habitat alteration, pH and sediment
Cd'A River	17010303 4020	Robinson Creek to Cave Lake	Habitat alteration, pH and sediment
Cd'A River	17010303 4015	Cave Lake to Black Lake	Habitat alteration, pH and sediment
Cd'A River	17010303 3529	Black Lake to Thompson Lake	Habitat alteration, pH, temperature and sediment
Cd'A River	17010303 4023	Thompson Lake to Cd'A Lake	Habitat alteration, pH and sediment
Latour Creek	17010303 3535	Headwaters to Cd'A River	Bacteria, habitat alteration, sediment and temperature
Baldy Creek	17010303 7535	Headwaters to Latour Creek	Bacteria, habitat alteration, sediment and temperature
Larch Creek	17010303 7536	Headwaters to Latour Creek	Bacteria, habitat alteration, sediment and temperature
Fourth of July Creek	17010303 3534	Headwaters to Cd'A River	Habitat alteration and sediment

Water body Name	HUC Number	Boundaries	Pollutant(s)
Willow Creek	17010303 3531	Headwaters to Cd'A River	Sediment
Black Lake	17010303 7529		Nutrients
Thompson Creek	17010303 3530	Headwaters to Cd'A River	Habitat alteration and sediment
Wolf Lodge Creek	17010303 3541	Headwaters to Cd'A Lake	Bacteria, habitat alteration, nutrients and sediment
Marie Creek	17010303 7541	Searchlight Creek to Wolf Lodge Creek	Habitat alteration
Cedar Creek	17010303 3541	Headwaters to Wolf Lodge Creek	Habitat alteration, oil and gas and sediment
Fernan Lake	17010303		Nutrients
Fernan Creek	17010303 3543	Fernan Lake to Cd'A Lake	Bacteria, dissolved oxygen, habitat alteration, nutrients and sediment
Cougar Creek	17010303 3545	NF Cougar Creek to Cd'A Lake	Habitat alteration, nutrients and sediment
Kidd Creek	17010303 3546	Headwaters to Cd'A Lake	Habitat alteration, nutrients and sediment
North Fork Mica Creek-Mica Creek	17010303 3547	Headwaters to Cd'A Lake	Bacteria, dissolved oxygen, habitat alteration, nutrients and sediment
Lake Creek	17010303 3549	House(Kruse?) Creek to Cd'A Lake	Sediment

Additional water bodies had been listed on the 1996 list. These are listed in Table 2. These water bodies were removed from the list when analysis of more recent water quality data indicated these streams are not presently water quality limited (IDEQ 1996c).

Table 2: List of additional water bodies included on the 1996 Section 303(d) list, but delisted as a result of sufficiently high water quality scores.

Water body	HUC Number	Boundaries	Pollutant(s)
Carlin Creek	17010303 3538	Headwaters to Cd'A Lake	Sediment
Turner Creek	17010303 3539	Headwaters to Cd'A Lake	Sediment
Fernan Creek	17010303 3544	Headwaters to Fernan Lake	Habitat alteration, nutrients, sediment and pathogens
Rockford Creek	17010303 3548	Headwaters to Cd'A Lake	Habitat alteration, nutrients and sediment

2.2.2. Beneficial Uses

Of the listed water bodies, the Coeur d'Alene River, Wolf Lodge Creek and Fernan Lake and its outlet creek have beneficial uses specifically designated in the Idaho Water Quality Standards

(IDAPA 16.01.02.) Beneficial uses of the other listed water bodies would be, by interpretation of the standards, cold water biota and secondary contact recreation (IDAPA 16.01.02101.01.a).

The Coeur d'Alene River has designated uses in the Idaho water quality standards (IDAPA 16.01.02110,01.ee.) of agricultural water supply, cold water biota, primary and secondary contact recreation and salmonid spawning. A use attainability and beneficial use status assessment was completed for the waters of the Coeur d'Alene Basin during 1992 (Hartz, 1993). All the designated uses were assessed as attainable. The river was assessed to be supporting agricultural water supply, primary and secondary contact recreation uses. Both cold water biota and salmonid spawning were assessed to be partially supported due primarily to exceedences of the zinc standard for the support of freshwater biota in the water column and concern that contaminated sediments may be affecting the freshwater biota through food chain interactions. Although Ellis (1940) reported the Coeur d'Alene River to be nearly devoid of all life to its mouth, more recent studies (Bauer, 1975; Hornig, Terpening and Bogue, 1988) indicate that self-sustaining populations of fish and macroinvertebrate species have returned to the river and the lakes of its floodplain. Macro-invertebrate numbers appear lower near the mouth and in the lower reaches of the river as compared to the control areas in the St. Joe River (Skille et. al., 1983). Phytoplankton productivity may also be affected by metals in the water column (Rabe, Wissmar and Minter, 1973). Adfluvial cold water fish (west slope cutthroat and bull trout (indigenous) and Chinook and Kokanee Salmon (introduced)) use the Coeur d'Alene River as a migratory route (Horner, personal comm.). A more thorough discussion of the Coeur d'Alene River and the lakes of its floodplain is provided in the Coeur d'Alene River Problem Assessment (IDEQ, 1997).

Wolf Lodge Creek (PB-360S) has designated uses of domestic water supply, agricultural water supply, cold water biota, salmonid spawning and primary and secondary contact recreation (IDAPA 16.01.02110,01.hh.). Fernan Lake and its outlet creek (PB-350S) have designated use of domestic water supply, agricultural water supply, cold water biota, salmonid spawning and primary and secondary contact recreation (IDAPA 16.01.02110,01.oo.).

2.2.3. Water Quality Standards

Water quality standards supportive of the designated beneficial uses are stated in the Idaho Water Quality Standards and Wastewater Treatment Requirements (IDHW 1996b). The criteria supporting the beneficial uses are outlined in Table 3. In addition to these criteria cold water biota and salmonid spawning are supported by two narrative criteria. The narrative sediment criterion states:

Sediment shall not exceed quantities specified in section 250 or, in the absence of specific sediment criteria, quantities which impair designated beneficial uses. Determinations of impairment shall be based on water quality monitoring and surveillance and the information utilized as described in Subsection 350.02.b.(IDAPA 16.01.02.200.08).

The excess nutrients criterion states:

Surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other aquatic growths impairing designated beneficial uses. (IDAPA 16.01.02.200.06).

Table 3: Water quality criteria supportive of beneficial uses.

Designated Use	Primary Contact Recreation	Secondary Contact Recreation	Cold Water Biota	Salmonid Spawning
Coliforms and pH	500 FC/100mL	800 FC/100mL	pH between 6.5 and 9.5	pH between 6.5 and 9.5
Coliforms and dissolved gas	200 FC/100mL geometric mean over 30days	400 FC/100mL geometric mean over 30 days	dissolved gas not exceeding 110%	dissolved gas not exceeding 110%
chlorine			total chlorine residual less than 19 ug/L/hr or an average 11 ug/L/4 day period	total chlorine residual less than 19 ug/L/hr or an average 11 ug/L/4 day period
toxics substances			less than toxic substances set forth in 40 CFR 131.36(b)(1) Columns B1, B2, D2	less than toxic substances set forth in 40 CFR 131.36(b)(1) Columns B1, B2, D2
dissolved oxygen			exceeding 6 mg/L D.O.	exceeding 5 mg/L intergravel D. O.; exceeding 6 mg/L surface
temperature			less than 22°C (72°F) instantaneous; 19°C (66°F) daily average	less than 13°C (55°F) instantaneous; 9°C (48°F) daily average
ammonia			low ammonia (formula/tables for exact concentration	low ammonia (formula/tables for exact concentration
turbidity			less than 50 NTU greater than background instantaneous; 25 NTU over 10 days greater than background	

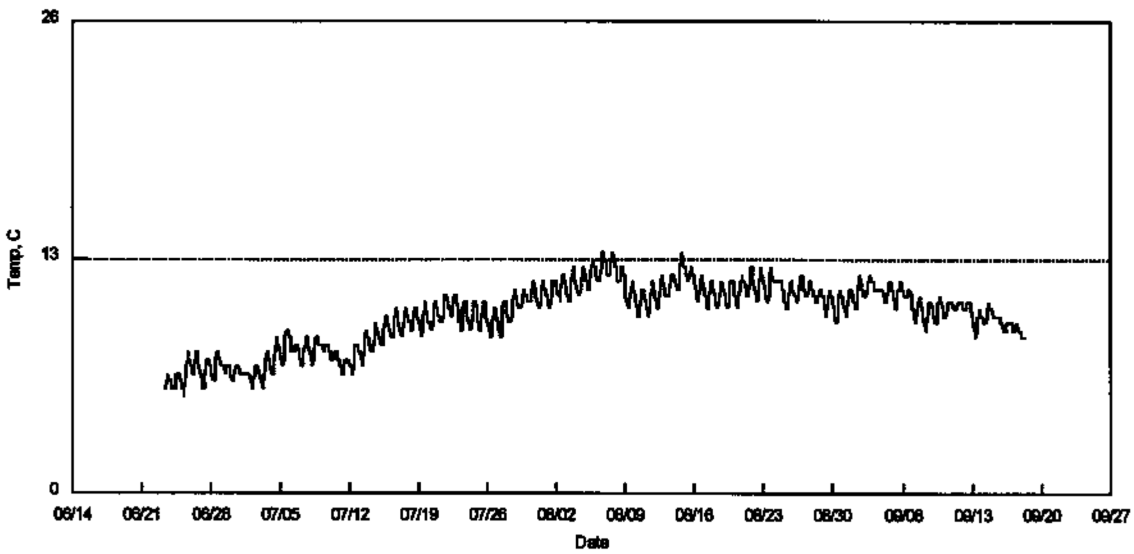
2.3. Water Quality Concerns and Status

The water quality concerns and status are addressed in the following sections by identifying potential pollutant sources and reviewing the existing data for the listed water bodies.

2.3.1. Pollutant Sources

The water bodies of the sub-basin placed on the 1996 list have reported pollutant exceedences for one or more of the following pollutants: bacteria, habitat alteration, nutrients, sediment, dissolved oxygen, oil and grease, pH and temperature. In most cases bacterial contamination would be predominantly from livestock grazing. Habitat alteration can occur from several actions. An incomplete list of these actions would include nearby road construction, removal of riparian vegetation, channelization or excess sedimentation. Excess nutrients normally are the result of human residential development or livestock grazing activities in the waters under assessment. Nutrients may also naturally build up in a lake over time causing a naturally eutrophic lake. Shallow lakes which have limited water flow through the lake on an annual basis are more likely to be

Figure 5: Baldy Creek Temperature Data Summer 1997



2.3.2.3. Black Lake:

Black Lake is a floodplain lake of the Coeur d'Alene River. The eleven floodplain lakes of the Coeur d'Alene River Valley are shallow, warm during the summer months and generally eutrophic (Table 6) (USGS 1993).

Table 6: Lateral Lakes Water Quality Nutrient Data 1992

Lateral Lake	Total Inorganic N (mg/L)	Total Organic N (mg/L)	Total P (mg/L)
Anderson	0.058	0.35	0.039
Black	0.020	0.85	0.046
Blue	0.021	0.20	0.010
Bull Run	0.021	0.35	0.063
Cave	0.033	0.25	0.058
Killarney	0.044	1.00	0.012
Medicine	0.016	0.35	0.085
Rose	0.252	0.80	0.058
Swan	0.078	0.55	0.013
Thompson	0.010	0.20	0.012

Note: Data not collected for Porter Lake

The generally accepted total phosphorous criterion for nuisance weed growth in lakes is 25 ug/L (USEPA, 1972). Black Lake total phosphorous values collected in 1992 (Table 6) and in 1997 (Table 7) indicate the lake is well above the criterion (approximately 50 ug/L). Table 6 indicates that eight of the ten lateral lakes measured are above the criterion and that Black Lake, is intermediate in its phosphorous level. The nutrient level of Black Lake and other lakes of the Coeur d'Alene River floodplain are typical of self-fertilizing eutrophic lakes (IDEQ, in draft). These lakes have likely been eutrophic for thousands of years (Rember, 1999). Organic and inorganic nitrogen levels support this interpretation. Eutrophy is simply a gauge of the nutrient status and age of the lake. The beneficial uses of Black Lake, which supports warm water biota, primary and secondary contact recreation, are not impaired by its eutrophic nature. The trophic status of Black Lake in relation to its expected condition as a small shallow floodplain lake does not support water quality limited listing for nutrients.

Table 7: Black Lake Water Quality Nutrient Data 1997

Location	Total Inorganic N (mg/L)	Total Phosphorous (mg/L)
Mid-lake	0.039	0.055

2.3.2.4. Wolf Lodge Creek

Absence of the reported bacteria contamination was found during the low discharge period of summer 1999. Bacterial samples from Wolf Lodge and Stella Creeks were analyzed from fecal coliform and E-coli. The streams were found to have 22 and 11 fecal coliform per 100 mL and 33 and 10 E-coli per 100 mL (BURP, 1999). These values are sufficiently well below the fecal coliform primary contact standards of 500 fecal coliform per 100 mL and the proposed recreational standard of 406 E. coli per 100 mL that no additional testing was deemed necessary.

Nutrients supportive of aquatic plant growth were assessed on water samples from Wolf Lodge Creek. Total phosphorous concentration was 14 ug/L as phosphorous. The guideline used by DEQ for interpretation of the excess nutrients narrative standard is 100 ug/L total phosphorous in flowing streams (USEPA, 1972). Total Kjeldahl nitrogen was 100 ug/L, while nitrate-nitrite analysis was 142 ug/L as nitrogen. The nitrogen data indicates that nearly all the nitrogen is in the form of nitrate-nitrite. The guideline for excess nitrate is 300 ug/L as nitrogen (Sawyer, 1947; Müller, 1953). The concentrations measured in Wolf Lodge Creek are less than half the guideline indicating the stream is not water quality limited by nitrogen.

2.3.2.5. Fernan Lake and Creek

A lake water quality assessment was completed on Fernan Lake during the 1991 field season (Mosier 1992). Nutrient data indicate the lake was mesotrophic (Table 8) and was not exceeding the nuisance weed growth criterion. Additional parameters collected in 1991 support the mesotrophic condition of Fernan Lake. Algal blooms have commonly been observed on the lake suggesting it is at or close to a eutrophic classification. The lake is currently in a state that intervention in the watershed could reduce phosphorous export to the lake and slow the pace of eutrophication. The possibility that the lake would become anoxic in its bottom waters is remote. The lake is relatively shallow (7 meters) allowing for wind driven re-oxygenation even at depth. Dissolved oxygen measurements completed at the time of the assessment showed bottom water to be low in oxygen during the summer (0.8 mg/L), but not anoxic. Water quality measurements collected to date from Fernan Lake do not violate water quality standards. However, the lake is close to violations and algal blooms occur on a yearly basis. An advisory TMDL should be developed for the lake based on further measurements of phosphorous loading.

Table 8: Fernan Lake Water Quality Average Nutrient Data

Location	Total Inorganic N (ug/L)	Total Phosphorous (ug/L)
mid-lake	50	21

Fernan Creek is listed for bacteria, dissolved oxygen, habitat alteration, nutrients and sediment. The stream currently has stable banks with stable vegetation. Sediment sources to the immediate stream are few and not severe. Upstream sources are precluded by Fernan Lake. No apparent source of bacteria exists. The habitat may have been altered in the past but stable habitats have reestablished along the stream. The stream is well shaded and shallow suggesting oxygen level would not be a problem. The pollutant listing on the 1998 303(d) lists may well date back to 1988 when the golf course and highway were under construction. A decade has past since the construction period. Vegetation has reestablished reducing sedimentation and producing habitats. The creek likely has a residual nutrient problem associated with its primary source of water, Fernan Lake, and possibly exacerbated by fertilization of the adjacent golf course.

Water samples from Fernan Creek were collected for fecal coliform and E coli analysis during the low discharge period of summer 1999. Analysis indicated four fecal coliform and ten E coli per 100 mL (BURP, 1999). These values are sufficiently well below the fecal coliform primary contact standards of 500 fecal coliform per 100 mL and the proposed recreational standard of 406 E. Coli per 100 mL that no additional testing was deemed necessary.

The stream likely does receive water enriched in nutrient from the lake. The golf course which flanks the west edge of the quarter-mile segment may also be a source of nutrients dependent on the turf management. The lower eighth-mile of stream fronts the golf course on one side. It is unlikely that a short segment would receive an important nutrient load or it would have an affect before discharge to the lake.

Nutrients supportive of aquatic plant growth were assessed on water samples from lower Fernan Creek. Samples were collected above the golf course. Total phosphorous concentration was 28 ug/L as phosphorous. The guideline used by DEQ for interpretation of the excess nutrients narrative standard is 100 ug/L total phosphorous in flowing streams (USEPA, 1972). The total phosphorous concentration measured for the creek is well below the guideline. Total Kjeldahl nitrogen was 230 ug/L as nitrogen, while nitrate-nitrite analysis was 290 ug/L as nitrogen. The nitrogen data indicate that most of the nitrogen is in the form of nitrate-nitrite. The guideline for excess nitrate is 300 ug/L as nitrogen (Sawyer, 1947; Müller, 1953). The concentration measured in lower Fernan Creek is quite close to the guideline, but below it. The high nutrient level most probably has its origin in Fernan Lake.

2.3.2.6. Cougar and Kidd Creeks

Nutrients supportive of aquatic plant growth were assessed on water samples from Cougar and nearby Kidd Creeks. Cougar Creek's total phosphorous concentration was 62 ug/L as phosphorous. Total Kjeldahl nitrogen was 190 ug/L as nitrogen, while nitrate-nitrite analysis was 156 ug/L as nitrogen. Kidd Creek's total phosphorous concentration was 43 ug/L as phosphorous. Total Kjeldahl nitrogen was 130 ug/L, while the nitrate-nitrite nitrogen measure was in error. The guideline used by DEQ for interpretation of the excess nutrients narrative standard is 100 ug/L total phosphorous in flowing streams (USEPA, 1972). Although Cougar and Kidd Creek's phosphorous concentrations are higher than expected, they are well below the guideline concentration. The guideline for excess nitrate is 300 ug/L as nitrogen (Sawyer, 1947; Müller, 1953). The concentration measured in Cougar Creek is roughly half the guideline. The Kidd Creek nitrogen data indicates the stream does not exceed the guideline, but additional testing of nitrate-nitrite is necessary. Unfortunately Kidd Creek does not flow late in the summer season.

2.3.2.7. Mica Creek

Water samples from Mica Creek and the North Fork Mica Creek were collected for fecal coliform and E. coli analysis during the low discharge period of summer 1999. Summer discharge measurements (2.5 cfs) indicate that secondary contact is the appropriate beneficial use for the stream. Both the acute (800 fecal coliform/ 100 mL) and chronic (geometric mean of 200 fecal coliform/100 mL) standards protective of secondary contact recreation were exceeded (Table 9). Analysis for E. coli was also made in anticipation of the proposed bacteria standard. Both the acute and chronic levels of this proposed standard were violated. The results indicate that Mica Creek and its North Fork are water quality limited by coliform bacteria. A TMDL addressing both the current fecal coliform and proposed E coli standards will be developed.

Table 9: Fecal and E. coliform bacteria from two locations on Mica Creek

Date	Mica Creek FC	Mica Creek EC	NF Mica Creek FC	NF Mica Creek EC
7/23/99	5100	2900	400	180
7/23/99		1300		200
7/27/99	570	150	600	130
7/30/99	730	630	500	380
8/4/99	800	220	720	190
8/24/99	570	300	600	300
Geometric Mean	993	535	553	216

Nutrients supportive of aquatic plant growth were assessed on water samples from Mica Creek and the North Fork Mica Creek. Total phosphorous concentration was 33 ug/L and 22 ug/L as phosphorous for Mica Creek and its North Fork, respectively. The guideline used by DEQ for interpretation of the excess nutrients narrative standard is 100 ug/L total phosphorous in flowing streams (USEPA, 1972). Total Kjeldahl nitrogen was 140 ug/L as nitrogen, while nitrate-nitrite analysis was 112 ug/L as nitrogen for Mica Creek. Total Kjeldahl nitrogen was 110 ug/L as nitrogen and 133 ug/L as nitrogen for the North Fork. The nitrogen data from both streams indicate that most of the nitrogen is in the form of nitrate-nitrite. The guideline for excess nitrate is 300 ug/L as nitrogen (Sawyer, 1947; Müller, 1953). The concentrations measured in Mica Creek and its North Fork are less than half the guideline, indicating the streams are not water quality limited by nitrogen.

2.3.2.8. Lake Creek

Considerable water quality monitoring has been completed on Lake Creek, most recently for 1996 through 1998 (Bauer, Golden and Pettit, 1998). The stream transports large amounts of fine sediment primarily from agricultural fields and stream banks during high discharge events. The most recent work has found statistically significant and strong correlations between turbidity, suspended sediment and total phosphate and the signal output of an optical particle sensor. During storm events turbidity caused by suspended sediment transport can rise well above the criterion of 50 NTU above measurements at the upstream background station.. Peak turbidities of 600 to 1,000 NTU were observed during these events. When the background station is comapred these values are well above the salmonid sight feeding criterion (Table 3), indicating the stream is water quality limited for sediment.

2.3.2.9. Sediment Data

Available sediment data for the streams and model results are summarized in the following sections.

2.3.2.9.1. Riffle Armor Stability

A quantitative index of stream bed instability is the riffle armor stability index (RASI)(Kappesser, 1993). The measurement is not of value for the Coeur d'Alene River below the reach terminating at Skeel Gulch (4018). The measurement is of value above this point and in the tributaries to the river and the lake. Unfortunately, data of this type has not been collected for any of the water quality limited segments of the sub-basin.

2.3.2.9.2 Residual Pool Volume

One consequence of stream sedimentation is a loss of pool volume through pool filling. The amount of pool volume in streams can be estimated using residual pool volume measurements. Residual pool volume is the volume a stream pool would occupy if the stream reached a zero discharge condition. Under this condition water would not flow over stream riffles, stream runs would hold little water and the pools would make up the majority of the wetted volume of the stream. Residual pool volume is calculated using a box model from measurements of average pool depth, average pool width, pool length and average pool tailout depth. Average pool tailout depth is subtracted from average pool depth to develop the third side of the box model. Residual pool volume is normally developed for a reach of stream twenty times bank full width in length. The values are normalized on the basis of pool volume per mile of stream. Residual pool volume increases with stream width. For this reason, residual pool volume values must be stratified by stream width to assess the relative amount of pool volume. Residual pool volume data for the water quality limited segments has been stratified by bankfull stream width (Table 10). The measurement has little meaning in the Coeur d'Alene River, which as a low gradient Rosgen C channel, is a single pool below the Cataldo boat ramp. It does help gage the level of sedimentation of smaller high gradient streams, especially in the Belt terrane. Residual pool volumes are adequate in Latour and Wolf Lodge Creeks. Volumes in Marie, Lake and Fourth of July Creeks appear diminished with respect to the amount measured in the much smaller Willow Creek. The lack of pools in Cougar, Kid and Mica Creeks may be the result of assessment of low gradient reaches of these streams or that these streams are located on granitic terrane with far more sand as sediment. This assessment has not been made on all water quality limited streams of the sub-basin.

Table 10: Mean residual pool volume and stream width for the water quality limited segments of the Coeur d'Alene Lake and River Sub-basin. Streams are stratified by bankfull width.

Stream	**HUC Number**	**Bank Full Width (ft)**	**Residual Pool Volume (ft^3/mi)**
Latour Creek	17010303 3535	24.7	34,969
Wolf Lodge Creek	17010303 3541	14.0	35,995
Marie Creek	17010303 7541	13.7	13,181
Lake Creek	17010303 3549	10.1	17,304
Fourth of July Creek	17010303 3534	10.0	18,737
North Fork Mica Creek-Mica Creek	17010303 3547	8.3	0
Cougar Creek	17010303 3545	7.8	0
Willow Creek	17010303 3531	6.9	45,678
Kid Creek	17010303 3546	6.0	0
Cedar Creek	17010303 3541	N.D.	N.D.
Fernan Creek	17010303 3543	N.D.	N.D.
Baldy Creek	17010303 7535	N.D.	N.D.
Larch Creek	17010303 7536	N.D.	N.D.
Thompson Creek	17010303 3530	N.D.	N.D.

Note: Data developed from IDEQ (Hartz, 1993)

2.3.2.10. Fish Population Data

Sedimentation can interfere with natural trout recruitment and cause the filling of pools. The effect may be reflected in the trout populations. Trout population density has been assessed in some tributaries of the lake and river by DEQ beneficial use reconnaissance teams. The Coeur d'Alene Tribe has developed fish population data for Lake Creek (Appendix A).

Cutthroat and brook trout are the salmonids found in these tributaries. Trout population densities (salmonid/m^2/ hour effort) of the listed segments are summarized in Table 11. Reference streams, elsewhere in the Coeur d'Alene River basin, range from 0.1 - 0.3 salmonid/m^2/hour effort (IDEQ, 1999). Similar population density was found for reference streams in granitic geologic settings near Priest Lake (Fitting and Dechert, 1997) It is necessary to default to these reference streams, because no appropriate references have been assessed in the sub-basin. Where data are available in the sub-basin, trout density values in most water quality limited segments are an order of magnitude lower than these reference values. The exceptions are Cedar and Cougar Creeks, which have values above the range of the reference values. Three age classes of salmonids were found only two streams; Latour and Cougar Creeks. Sculpin population density was typically found in a range of 0.1 - 0.5 fish/m^2/hour effort in reference streams (IDEQ, 1999). This range or slightly higher was found in sub-basin streams where data is available, except for Mica Creek. Sculpin may not be favored by the sandy bottom of this stream, where cobble is not available for the cover these fish use. Tailed frogs were found exclusively in Cedar Creek.

Table 11: Fish population per unit stream area of the water quality limited segments of the Coeur d'Alene Lake and River Sub-basin.

Stream	HUC Number	Salmonid Density ($fish/m^2/hr$ effort)	Presence of Three Salmonid Age Classes	Sculpin Density ($fish/m^2/hr$ effort)	Presence of Sculpin and/or Tailed Frogs
Coeur d'Alene River	17010303 3529 - 4023	N.D.	N.D.	N.D.	N.D.
Latour Creek [1]	17010303 3535	0.0271	Yes	0.1834	No
Baldy Creek	17010303 7535	N.D.	N.D.	N.D.	N.D.
Larch Creek	17010303 7536	N.D.	N.D.	N.D.	N.D.
Fourth of July [1] Creek	17010303 3534	0.0529	No	0.6247	No
Willow Creek	17010303 3531	N.D.	N.D.	N.D.	N.D.
Thompson Creek	17010303 3530	N.D.	N.D.	N.D.	N.D.
Wolf Lodge Creek [1]	17010303 3541	0.0639	No	0.7204	No
Marie Creek	17010303 7541	N.D.	N.D.	N.D.	N.D.
Cedar Creek [1]	17010303 3541	0.6570	No	0.5734	Yes
Fernan Creek	17010303 3543	N.D.	N.D.	N.D.	N.D.
Cougar Creek [1]	17010303 3545	0.4537	Yes	0.3871	No
Kid Creek	17010303 3546	N.D.	N.D.	N.D.	N.D.
North Fork Mica [1] Creek-Mica Creek	17010303 3547	0.0600	No	0.0480	No
Lake Creek [2]	17010303 3549	0.0279	No	N.D.	N.D.

Note: 1- data from DEQ beneficial use reconnaissance program; 2 - data from Coeur d'Alene Tribe; N.D. - no data

2.3.2..11. Sedimentation Estimates:

2.3.2.11.1. and Use Type Areas, Road Density and Impacts

Several tributaries to the lake and river are listed as water quality limited for sediment impacts. The river is affected by sediment in its upper segments above Skeel Gulch. Below Skeel Gulch, the river is gradient limited from carrying sediment particles larger than a fine grain of sand and is insulated from tributary sedimentation by its broad floodplain. As discussed earlier, sedimentation of the upper segments is the result of sediment loads primarily from the North and South Forks of the River. These impacts must be addressed in those watersheds.

Land use areas and roads information is required to model sedimentation. It was developed from

Geographical Information Systems (GIS) coverages. Existing coverages of land use and road systems developed by the Forest Service (CDASTDS) and Idaho Department of Lands were used where these were available (Wolf Lodge Creek). Where these were not available, canopy coverage was developed using USGS digital orthophoto quadrangles. Canopy coverage was ground verified by CWE crews cumulative watershed effects. Road coverage was available through the Idaho Department of Lands (IDL) from the Forest Service, timber companies and the counties. Forest fire coverage was supplied by the Forest Service (IPFIRES) All constructed GIS coverages were developed by Idaho Department of Lands personnel. Land use and roads data is presented in Table 12. After assessment of the watersheds by Idaho Department of Lands specialists, cumulative watershed effects (CWE) scores were developed. Additional sediment model assumptions and documentation are in Appendix B.

2.3.2.11.2. Sediment Yield and Export Coefficients

Sediment yields were developed separately for agricultural, forest lands and forest roads. The models used assume 100% export of the yielded sediment to the stream.

2.3.2.11.2.1. Agricultural Land Sediment Yield and Export.

Sediment yield was estimated from agricultural lands (pasture and dry agriculture) using the Revised Universal Soil Loss Equation (RUSLE) (equation 1)(Hogen, 1998).

Equation 1: $A = (R)(K)(LS)(C)(D)$ tons per acre per year where:

: A is the average annual soil loss from sheet and rill erosion
: R is climate erosivity
: K is the soil erodibility
: LS is the slope length and steepness
: C is the cover management and
: D is the support practices.

RUSLE does not take into account bank erosion, gully erosion or scour. RUSLE applies to cropland, pasture, hayland or other land which has some vegetation improvement by tilling or seeding. Based on these soils characteristics of the agricultural land, the slope, sediment yield was developed for the agricultural land use of each watershed (Table 13). Sediment yield from agricultural lands was estimated by applying the sediment yield coefficients to the land area in agricultural use (Table 15).

2.3.2.11.2.2. Forest Land Sediment Yield and Export

Forest land sediment yield was based on sediment production rates used in the Forest Service WATSED Model (Patten, personal comm.). These are 25 tons per square mile per year with a range from 22-35 for the Kaniksu granitic terrane and 15 tons per square mile per year with a range from 12-17 for the Belt Supergroup terrane. The mean values were used for all conifer

Table 12: Land use of selected watersheds draining to Coeur d'Alene Lake and River.

Watershed	Wolf Lodge Creek	Cedar Creek	Cougar Creek	Kid Creek	Mica Creek	Thompson Creek	Willow Creek	Fourth of July Creek	Baldy Creek	Larch Creek	Latour Creek[2]
Pasture/ dry ag (ac)	946	77	869	906	422	820	453	1,548	0	0	257
Conifer forest (ac)	27,254	11,128	1,589	750	2,385	1,587	3,386	16,193	5,372	548	23,181
Unstocked forest (ac)	121	26	2,025	833	3,475	80	36	165	145	0	3,855
Highway (ac)	85	358	59	38	62	0	0	336	0	0	0
Forest Road (mi)	197.2	92.2	50.0	18.0	40.0	21.0	22.5	77.6	48.2	0.5	186.9
Forest road density (mi/mi^2)	4.6	5.7	3.0	3.1	1.7	5.4	3.7	2.8	5.4	0.6	4.4
Stream crossings	58	23	66	10	47	23	16	76	12	0	65
Road Crossing Frequency[3]	0.5	0.2	1.6	0.8	0.9	2.2	1.5	1.2	1.1	0	0.5
Road Contributing (mi)	4.4	1.7	5.0	0.8	3.6	1.7	1.2	5.8	0.9	0	4.9
Road encroaching (mi)	8.8	6.3	1.9	0.3	1.6	1.3	0.9	0.4	0.4	0	6.4
CWE Score	18.9	18.9	15	10	17.8	17.3	24.6	20.2	13.3	13.3	13.3

Table 13: Estimated sediment yield coefficients dry agriculture, pasture and rangelands. [1]

Watershed	Wolf Lodge Creek	Cedar Creek	Cougar Creek	Kidd Creek	Mica Creek	Thompson Creek	Willow Creek	Fourth of July Creek	Latour Creek
Rangeland (tons/ac/yr)	0.040	-	0.321	0.391	0.541	0.541	0.240	0.741	-
Pasture (tons/ac/yr)	0.030	0.040	0.030	0.050	0.050	-	0.040	0.030	0.020

[1] Pasture, and dry agriculture, sediment production and export based on the revised universal soil loss equation for lands of 0-2% slope.

Table 14: Estimated sediment yield coefficients for forest land uses on the terrane of the watersheds.

Land use type sediment export coefficient	(Kaniksu) Granitic Terrane	(Belt Supergroup) precambrium meta sediments Terrane
Conifer forest (tons/ha/yr)[1]	0.038	0.023
Unstocked forest (tons/ac/yr)[1]	0.055	0.027
Areas of double fire tons/acre/yr)	0.017	0.004
Highway (tons/ac/yr)[2]	0.034	0.019

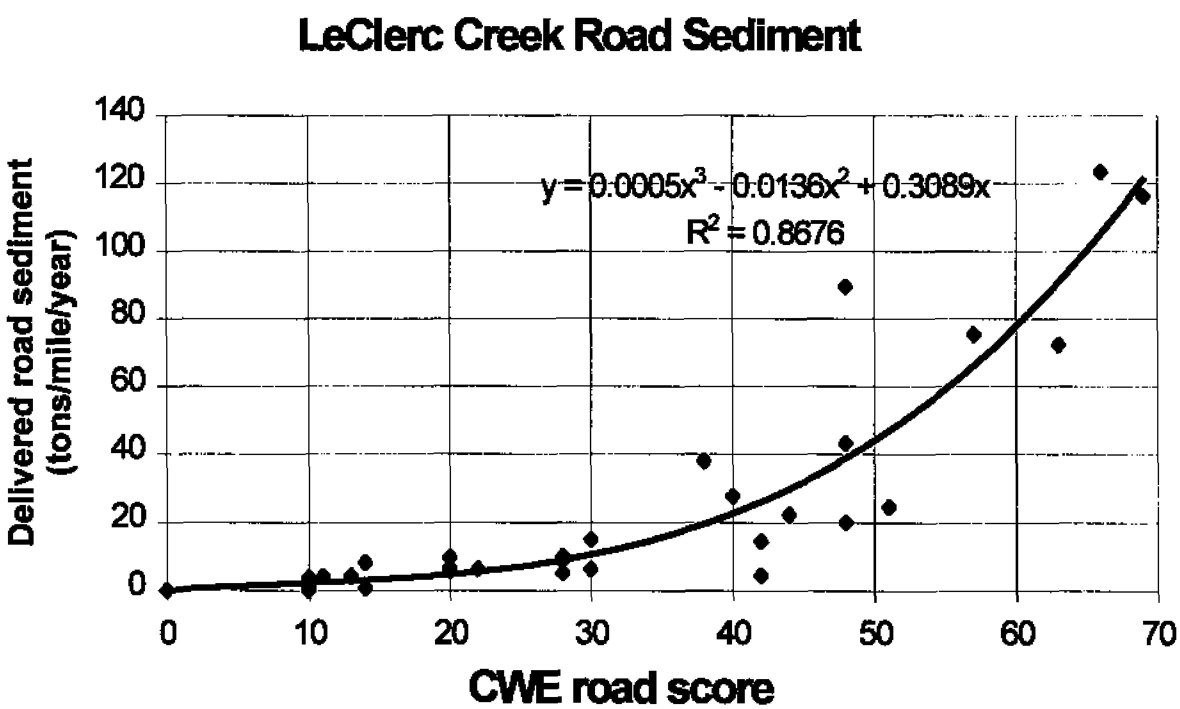
[1] Forest "natural" sediment production rates based on 25 tons/mi² /yr (range 22-35) from Kaniksu granitics and 15 tons/mi²/yr (range 12-17) for Belt Supergroup terranes. All conifer forest except unstocked acreage assumed to have median export coefficient. Unstocked forest lands(lands not meting FPA stocking rate) assumed to have the highest export coefficient. Areas of double fires adjusted to highest coefficient.

forest, which was fully stocked. The highest values in the range were used for parcels which were not fully stocked with trees, based on the Idaho Forest Practices Act standards. The lowest value for the Belt and Kaniksu terrane were applied to highway rights of way (Table 14). Sediment yield from forest lands was estimated by applying the sediment yield coefficients to the land area in forest use (Table 15). It was assumed all yielded sediment was delivered to the stream system.

2.3.2.11.2.3 Forest Roads

Forest road sediment yield was estimated using a relationship between CWE score and the sediment yield per mile of road (Figure 6). The relationship was developed for roads on a Kaniksu granitic terrane in the LaClerc Creek watershed (McGreer, pers comm.). Its application

Figure 6: Sediment export of roads based on Cumulative Watershed Effects



to roads on Belt metamorphic terranes conservatively overestimates sediment yields from these systems. The watershed CWE score was used to develop a sediment load in tons per mile, which was multiplied by the estimated road mileage in the watershed yield total sediment load to streams. This road surface directly contributing was assumed to be that located 200 feet on either side of a stream crossing. (Table 12). In the case of roads, it was assumed that all sediment was delivered to the stream system. These assumptions conservatively over estimate actual delivery.

Roads deliver sediment to streams through two additional mechanisms. Road fills associated with stream crossings can fail. Based on the CWE data base, the actual fill failure and delivery was estimated. Fill failures are known to occur primarily during discharge events which reoccur every 10 - 15 years. The CWE data was divided by 10 years to estimate the watershed sedimentation from road failures in tons of sediment per year. The estimates were applicable to the specific watershed for which the CWE data were collected. The watershed wide impact was developed from road fill failure and delivery data from the road assessment scaled up by a factor reflecting the total roads in the watershed. Road fills are composed not only of fines, but course material as well. Since the road bed is most often built from the B and C horizons of the soil on hand, the percentage of fines from fill failures as compared to the course fraction (pebbles and larger). These estimates are developed from weighted averages of the major soils series of the watershed based on the STATSGO coverage of soils. Weighted averages were developed for each watershed from the weighted averages of the horizons of the major soil series in each map unit composing the watershed (Dechert, 1999)(Appendix B). These percentages are applied to the sediment yields to estimate the fines exported to the streams as compared to the pebble and larger fraction.

Many roads are sited in locations which encroach on the floodplain of the stream. This construction practice often alters the gradient of the stream. The gradient is effectively increased, because the stream length is shortened. The stream uses the resulting additional stream power to erode material and regain stream length to move towards its original steady-state gradient. The result is increased erosion and sediment export, either from the road bed or, if this is armored, from the bed and banks of the stream itself. Roads fifty feet from streams were assumed to be encroaching. The amount of erosion and subsequent sediment delivery is estimated based on the miles of encroaching stream. The bulk of the erosion is assumed to occur during the large discharge events occuring every 10 - 15 years. The materials eroded are primarily the native soils of the area with their characteristic distribution of fines and course materials. These percentages are estimated from the major soils series of the watershed. The gross deliver was divided by ten to account for the episodic nature of the mechanism's sediment delivery. Additional details on the sediment model used are available in Appendix B. The model spreadsheets for those watersheds modeled are in Appendix C.

2.3.2.11.2.4. County and Private Roads

County and private road surface erosion was modeled with the RUSLE model (Sandlund, 1999). Based on slope length, soil type and surface material, a coefficient of tons per acre per year was developed. These coefficients were applied to the area of the road 200 feet on either side of stream crossings. Since the width of county and private roads is set by ordinance, an acreage associated with this distance could be calculated.

Road fill failure and encroachment were treated as the forest roads. The CDAROADS GIS coverage maps all roads; county, private and forest.

2.3.2.11.2.4 Sedimentation Estimates

Sedimentation estimates were developed by addition of the various sediment yields. The models (RUSLE, WATSED) and methods used assume complete delivery to the stream channels (Table 15).

Table 15: Estimated sediment export of watersheds listed for sediment impairment.

Watershed	Wolf Lodge Creek	Cedar Creek	Cougar Creek	Kidd Creek	Mica Creek	Thompson Creek	Willow Creek	Fourth of July Creek	Baldy Creek	Larch Creek	Latour Creek
Pasture/ dry ag (tons/yr)	28.4	2.3	78.3	88.6	130.3	24.7	18.1	46.4	0.0	0 0	5.1
Conifer forest (tons/yr)	626.9	256.0	298.5	71.7	463.9	43.0	77.9	372.4	123.6	12.6	533.2
Unstocked forest (tons/yr)	3.2	0.8	10.4	4.3	3.6	2.2	1.0	4.5	3.9	0.0	104.1
Highway (tons/yr)	1.6	6.8	2.0	1.3	2.1	0.0	0.0	6.4	0.0	0.0	0.0
Road Crossing Fine (tons/yr)	53.3	30.2	25.0	8.8	36.3	13.9	12.1	55.4	4.5	0.0	30.8
Road Fills (tons/yr)	0.1	1.4	42.7	0.0	3.3	0.0	0.0	1.3	0.0	0.0	38.7
Road Encroaching (tons/yr)	47.2	33.8	10.2	1.6	8.6	7.0	4.8	2.7	2.2	0.0	72.9
Bank Erosion (tons/yr)	33.0	-	-	-	-	-	-	-	-	-	-
Total (tons/yr)	792.7	331.3	476.1	176.3	647.8	90.8	117.9	489.1	134.2	12.6	784.8

2.3.3 Beneficial Use Support Status

Water bodies were not assessed for habitat alteration. Current Division of Environmental Quality Policy does not recognize habitat alteration as a quantifiable and therefore allocatable parameter. Temperature standards are currently under review to assess their applicability. Water bodies requiring thermal TMDLs are being deferred until this review is complete. The assessed support status of the water bodies based on the data available is provided in column 4 of Table 16. The need for development of a TMDL is noted. Column five explains why TMDLs are not needed for some pollutants listed on the 1998 303(d) list.

Table 16: Results of Water body assessment based on application of the available data.

Water body Name	HUC Number	Boundaries	Assessed Support Status	Reasons TMDL not required for pollutants
Cd'A River	17010303 4021	SF Cd'A R to French Gulch	limited by sediment [1,3]	pH data provided Table 4
Cd'A River	17010303 4018	French Gulch to Skeel Gulch	limited by sediment [1,3]	pH data provided Table 4
Cd'A River	17010303 4022	Skeel Gulch to Latour Creek	limited by temperature	pH data provided Table 4 Sediment not impairing use
Cd'A River	17010303 4019	Latour Creek to Fourth of July Creek	limited by temperature	pH data provided Table 4 Sediment not impairing use
Cd'A River	17010303 4017	Fourth of July Creek to Fortier Creek	limited by temperature	pH data provided Table 4 Sediment not impairing use
Cd'A River	17010303 4016	Fortier Creek to Robinson Creek	limited by temperature	pH data provided Table 4 Sediment not impairing use
Cd'A River	17010303 4020	Robinson Creek to Cave Lake	limited by temperature	pH data provided Table 4 Sediment not impairing use
Cd'A River	17010303 4015	Cave Lake to Black Lake	limited by temperature	pH data provided Table 4 Sediment not impairing use
Cd'A River	17010303 3529	Black Lake to Thompson Lake	limited by temperature	pH data provided Table 4 Surface temperatures exceedences in Table 5 not expected at depth; HOBO data indicates standard exceedence ;. Sediment not impairing use
Cd'A River	17010303 4023	Thompson Lake to Cd'A Lake	limited by temperature	pH data provided Table 4 Sediment not impairing use
Latour Creek	17010303 3535	Headwaters to Cd'A River	impaired by temperature and sediment	bacteria below standard (section 3.2.2.2.)

eutrophic. Any water body, which has its source in a eutrophic lake, will itself be rich in nutrients. Sediment is a water constituent naturally yielded from erosion of the watersheds to water bodies in question. Excess sedimentation in these watersheds most often has its origin in roads developed for logging or access to a watershed and bank erosion associated with grazing. Roads may yield sediment directly from their surfaces or bed through mass wasting or their locations may cause the adjacent stream to begin bank cutting or incising its bed. Dissolved oxygen may be deficient in lakes and some streams as the result of the presence of biological oxygen demanding materials. Often eutrophic lakes have sufficient algal and weed growth to engender dissolved oxygen problems. Streams may have insufficient dissolved oxygen as a result of temperature exceedences. Oxygen solubility declines with increased water temperature. Temperature exceedences in these waters are often due either to insufficient water flow, alteration of the stream structure to a broad shallow morphology or lack of riparian vegetation to supply shading (Platts, Megahan and Minshall., 1983). Streams which have their source in shallow warm lakes often are warm as well. Oil and grease can be yielded to the streams by major roads such as an Interstate. Oil may be yielded after rains to nearby streams. Oil and tar have been spilled during accidents on these roads and these materials can find their way into the nearby streams. Excessively low pH normally results from acid mine drainage or from mill tailings materials associated with mining. Although a few natural acid rock drainages can be found in the sub-basin, data indicates these do not alter the pH of streams, significantly.

2.3.2. Available Water Quality Data

The available data for the water bodies of the 1998 list are provided in the following sections.

2.3.2.1. Coeur d'Alene River

Water temperature and pH data have been collected on the Coeur d'Alene River as part of three years of metals monitoring. The pH data are from composite water samples collected monthly or bimonthly at the Cataldo, Rose Lake and Harrison monitoring stations (Table 4). The recorded pH values range between 6.5 and 7.5 and consistently have mean values above neutrality. These are typical pH values for the waters of northern Idaho. The data do not indicate any exceedence of the general aquatic pH standard (6.5-9.5)(IDAPA 16.01.02250.02.a.i.). Water temperature data were collected near the shore at the three monitoring stations as a part of the sampling procedure (Table 5). Water temperatures exceed cold water biota criteria in a very few cases during warm summers. Since these data were collected near shore, they are likely a few degrees warmer than water temperature offshore and at depth in the river. A few midsummer shore temperatures were in excess of the cold water biota standard (22°C)(IDAPA 16.01.02.250.c.ii.). Data developed by Golder and Associates (1998) support the data collected by DEQ, but none of these data were collected at depth in the river. In addition, sufficient data were not available to assess the daily average temperature cold water biota standard. To address this data gap, water temperature was continuously measured at the Harrison and Bull Run Bridges during the summer of 1999. The sensors were placed at four levels and three locations in the river at the Harrison Bridge and at two levels in the river at the Bull Run Bridge. The results from the eight sensors at the Harrison Bridge were remarkably similar. The between early July and late September. A lower number of exceedences occurred at depth. At the Bull Run Bridge the standard was exceeded 10% of the period at depth and 16% nearer the surface. The results indicate the river, which is too broad to be shaded, warms as it flows slowly downstream to the lake. However, the river exceeds the average temperature standard for cold water biota upstream. These results demonstrate the river is exceeding the current temperature standard for cold water biota.

Salmonid spawning occurs only in the reach of the river between the confluence of the North and South Forks of the river and Skeel Gulch (segments 4021 and 4018). This reach has riffles and

Table 4: Mean and deviation of pH data collected for three water years at the Cataldo, Rose Lake and Harrison Monitoring Stations on the Coeur d'Alene River.

	pH Data for W Y 1995		pH Data for W Y 1996		pH Data for W Y 1997	
Station	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Cataldo	7.09	0.24	7.23	0.22	7.12	0.15
Rose Lake	7.06	0.31	7.29	0.27	7.15	0.17
Harrison	7.15	0.21	7.11	0.17	7.20	0.19

gravels conducive to spawning. This reach has chinook salmon (September 15 to April 1) rainbow and cutthroat trout (January 1 to July 15) and whitefish (October 1 and April 1) spawning(IDAPA 16.01.02.250.d.iv.). The Cataldo monitoring station is located on this upper reach of the river. Temperatures are sufficiently low for whitefish spawning. (<13°C)(IDAPA 16.01.02250.d.ii.). Temperatures recorded in September exceed numeric temperature standards for chinook salmon spawning. Temperatures recorded in June and July exceed numeric temperature standards for rainbow and cutthroat trout spawning. The thermograph data collected downstream during the summer 1999 suggests that salmonid spawning temperature standards are violated. On the weight of the available evidence it appears that numeric salmonid spawning standards are regularly exceeded in the upper reach of the river.

Despite these temperature measurements, young of the year trout and salmon are easily observed along the upper reach of the river. Observation of numerous young of the year is normally taken as a strong indication that spawning is successful. This observation suggests that trout and salmon have acclimated or adapted to temperature conditions by spawning earlier in the case of rainbow and cutthroat or delaying until later in the case of chinook salmon to take advantage of cooler stream conditions.

Table 5: Temperature Data for the Coeur d'Alene River .																
Water Year1995																
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Apr	May	May	Jun	Jun	Jul	Jul	Aug	Sep
CATALDO						5.0	5.0	7.0	7.9	10.5	14.0	14.5	16.0	16.0	15.5	17.0
ROSE LAKE						5.0	5.0	9.0	9.0	13.0	16.0	17.0	19.0	19.0	16.0	18.0
HARRISON						5.5	3.5	9.0	9.0	15.0	15.0	19.0	22.0	21.0	19.0	20.0
Water Year1996																
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep				
CATALDO	9.0	4.0	1.0	1.5	0.0		5.0	7.5	11.0							
ROSE LAKE	9.5	4.5	1.0	1.5	0.0		5.0	8.0	11.0							
HARRISON	9.0	6.5	1.5	2.5	1.0		6.0	9.0	14.0							
Water Year1997																
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep				
CATALDO	8.0	5.0	2.0	2.0	2.0	5.0	7.0	6.9	10.2	15.7	17.0	16.0				
ROSE LAKE	8.0	4.0	3.0	1.5	3.0	5.0	6.5	8.8	11.5	18.3	19.2	17.4				
HARRISON	8.0	5.0	3.0	1.0	4.0	6.0	7.0		13.6	19.9	21.6	20.2				
Water Year1998																
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep				
CATALDO	11.4	5.4	3.6	2.8	3.1	4.2	8.0	7.3	13.1	20.1	17					
ROSE LAKE	10.8	5.0	3.8	3.1	3.5	4.3	8.5	8.0	14.9	23.0	19					
HARRISON	11.4	4.9	3.3	2.7	3.8	4.4	9.9	8.9	15.6	25.2	21					
Note.																
Temperature in degrees centigrade.																
Temperature taken from the bank.																

3.2.2.2. Latour, Larch and Baldy Creeks:

Latour Creek and its tributaries, Larch and Baldy Creeks, had continuous temperature measurement during the summer of 1997. These data (figures 3-5) indicate that temperatures supportive of cold water biota are maintained by these streams year-round. The principle spawning salmonids of these drainages would be cutthroat and brook trout and whitefish. Temperature data are not available for the October 1 to April 1 spawning period of brook trout and cutthroat trout. This period is bracketed by the warmer summer and early fall period. The data suggest the temperature standard is not exceeded during the fall and winter incubation months. The data do indicate the salmonid spawning temperature standard (<13°C)(IDAPA 16.01.02250.d.ii.) was exceeded during July 1997 on these streams.

Bacteria are also listed as a pollutant of concern on these three streams. These are largely forested watersheds with some dispersed residential development along lower Latour Creek. The Bureau of Land Management has land management responsibilities in these watersheds. No current grazing permits are operating in these watersheds. The last permits were terminated in 1988 (BLM, 1998). The absence of livestock grazing in a significant amount would suggest bacterial contamination is no longer an issue in these sub-watersheds. No other significant bacterial sources exist.

The lack of bacteria contamination was confirmed during the low discharge period of summer 1999. Water samples from Larch, Baldy and Latour Creeks were analyzed for fecal coliforms and *Escherichia coli* (E-coli). The Baldy and Latour Creeks were found to have seven or less per 100 mL in each case. Larch Creek had slightly higher fecal coliform and E coli counts of 28 and 20 per 100 mL, respectively (BURP, 1999). These values are sufficiently well below the fecal coliform primary contact standards of 500 fecal coliform per 100 mL and the proposed recreational standard of 406 E. coli per 100 mL that no additional testing was deemed necessary.

Figure 3: Latour Creek Temperature Data Summer 1997

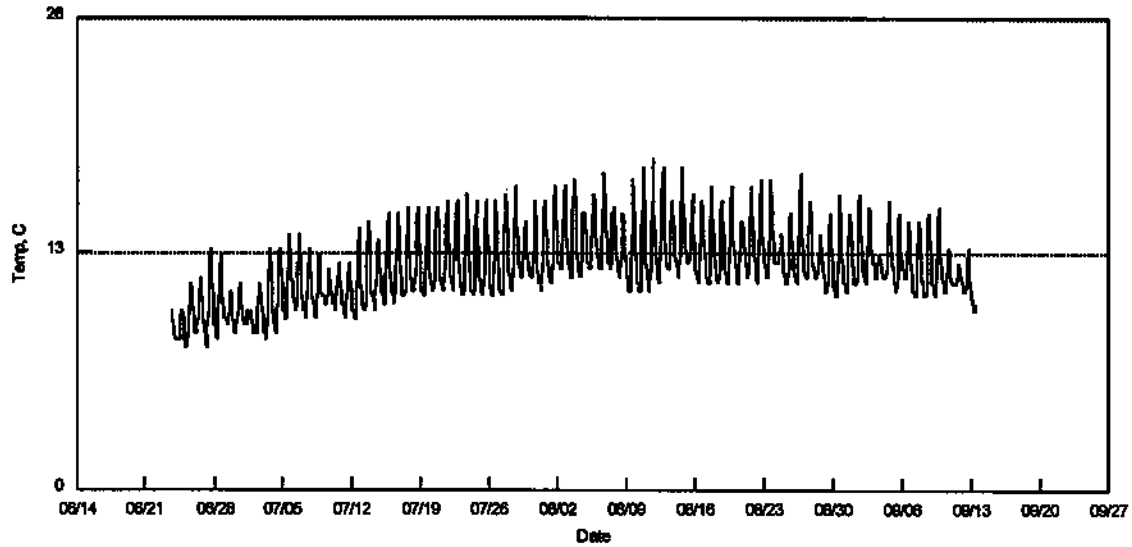
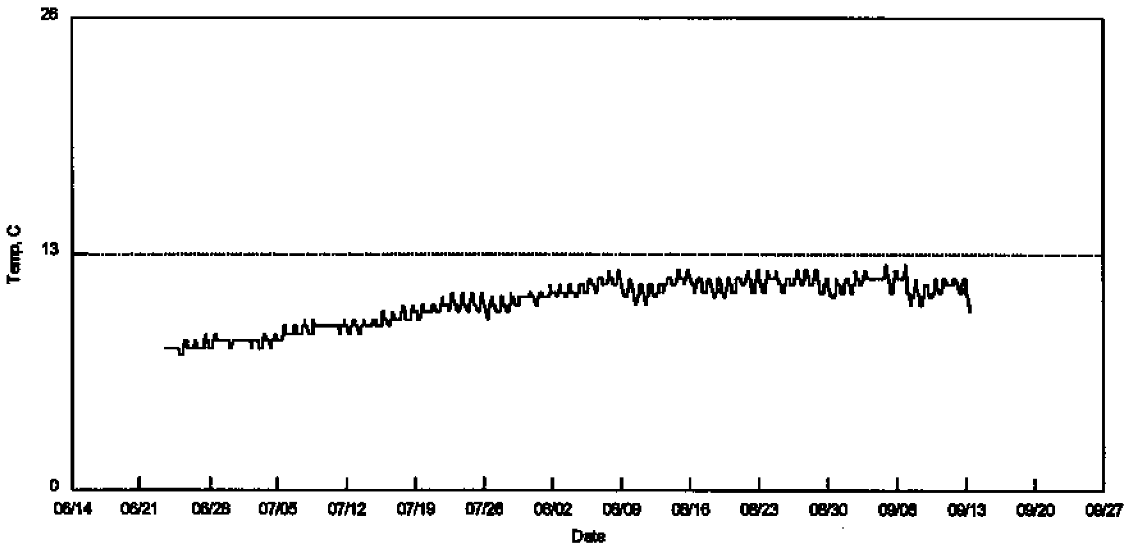


Figure 4: Larch Creek Temperature Data Summer 1997



Water body Name	HUC Number	Boundaries	Assessed Support Status	Reasons TMDL not required for pollutants
Baldy Creek	17010303 7535	Headwaters to Latour Creek	limited by temperature	bacteria below standard (section 3.2.2.2.) ;excessive sedimentation not found Table 15
Larch Creek	17010303 7536	Headwaters to Latour Creek	limited by temperature	bacteria below standard (section 3.2.2.2.) ; excessive sedimentation not found Table 15
Fourth of July Creek	17010303 3534	Headwaters to Cd'A River	not impaired	excessive sedimentation not found Table 15
Willow Creek	17010303 3531	Headwaters to Cd'A River	not impaired	excessive sedimentation not found Table 15
Black Lake	17010303 7529		not impaired	nutrients typical of eutrophic lake Table 6
Thompson Creek	17010303 3530	Headwaters to Cd'A River	not impaired	excessive sedimentation not found Table 15
Wolf Lodge Creek	17010303 3541	Headwaters to Cd'A Lake	impaired for sediment	bacteria and nutrients below standards (2.3.2.4.)
Marie Creek	17010303 7541	Searchlight Creek to Wolf Lodge Creek	TMDL not applicable[5]	habitat alteration not allocatable
Cedar Creek	17010303 3541	Headwaters to Wolf Lodge Creek	limited by sediment	oil and grease not found in stream
Fernan Lake	17010303		not impaired, but advisory TMDL recommended; year 2000	nutrients lower than weed growth guideline 25 ug/L Table 8
Fernan Creek	17010303 3543	Fernan Lake to Cd'A Lake	not impaired	stream re-stabilized after highway and golf course construction; bacteria and nutrients below standards (section 2.3.2.5.)
Cougar Creek	17010303 3545	NF Cougar Creek to Cd'A Lake	impaired by sediment	nutrients below guideline (section 2.3.2.6.)
Kid Creek	17010303 3546	Headwaters to Cd'A Lake	not impaired	nutrients below guideline (section 2.3.2.6.): excessive sedimentation not found Table 15
North Fork Mica Creek-Mica Creek	17010303 3547	Headwaters to Cd'A Lake	impaired by sediment and bacteria	Nutrients below guideline (section 2.3.2.7.)
Lake Creek	17010303 3549	House(Kruse?) Creek to Cd'A Lake	impaired by sediment	

1. Sedimentation must be addressed in South and North Fork Coeur d'Alene River TMDLs
2. Except for metals addressed in Coeur d'Alene River Metals TMDL.
3. Temperature likely limiting.
4. Sedimentation data incomplete. Treat as part of a Latour Creek TMDL.
5. Treat as part of a Wolf Lodge-Cedar Creeks TMDL.

The TMDLs required for HUC 17010303 can be grouped in some cases. The two most upstream segments of the Coeur d'Alene River are sediment impaired. This impairment is the result of sediment delivery from the North and South Forks of the river. Below Skeel Gulch sediments are fine and the river is at a sufficiently low gradient that the bed consists of fine sand rather than cobble bedded. In this case sedimentation does not impact beneficial use directly as in higher gradient channels. The sediment impairment above Skeel Gulch must be addressed in the source areas of the North and South Fork Coeur d'Alene Rivers.

Sediment and temperature impair Latour Creek. Its tributaries Baldy and Larch Creeks were found to be temperature impaired. Baldy and Larch Creeks will be treated in a Latour Creek TMDL which addresses excessive sedimentation. Temperature TMDLs have been postponed pending resolution of Idaho's temperature standards.

Wolf Lodge Creek and its tributary Cedar Creek appear from the sediment analysis to have elevated sedimentation. Although Marie Creek was not listed for sediment it will be treated in a Wolf Lodge Creek TMDL which also will address Cedar Creek. Individual sediment TMDLs will be required for Cougar, Kidd and Mica Creeks. A bacteria TMDL is required for Mica Creek.

A sediment TMDL is required for Lake Creek. The segment listed is located within the boundaries of the Coeur d'Alene Reservation making this TMDL the lead responsibility of the Environmental Protection Agency (EPA). Lake Creek had an active State Agricultural Water Quality Program (SAWQP). The program plan is with some rearrangement and the addition of an in-stream water quality goal, essentially a TMDL. A loading analysis and allocation are present in the current plan. Either the EPA or the Natural Resource Conservation Service could reshape the existing program plan into a TMDL. Implementation of that plan is currently underway.

2.4. Pollution Control

Some water pollution controls have been implemented. These are discussed in the following sections together with the pollution control strategies.

2.4.1. Control Efforts to Date

Pollution control efforts to date have been in place on some of the watershed requiring additional TMDL measures.

Analysis of sediment in eleven watersheds of the basin indicates roads are the primary sediment producing infrastructures. Forest harvest methods have progressed from logging systems heavily dependent on haul roads to those less dependent of high road densities. At certain log prices, helicopter logging has become a viable alternative in some watersheds. Unfortunately, an inventory of old roads continue to yield sediment to the streams. The U.S. Forest Service has carried out an aggressive program of forest road retirement and obliteration in the past five years. These efforts should have some beneficial effect primarily in the Wolf Lodge Creek watershed. The Latour, Cougar and Mica Watersheds contain very limited or no lands under Forest Service Management.

The Forest Service Program has sought to obliterate entire roads. Recent analysis indicates roads cause sediment loading primarily near road crossings of streams and where roads are located within the stream floodplain causing gradient changes. Scarce funds obtained by the Forest Service might be better targeted on the sediment yield areas rather than on obliteration of the entire road.

Kootenai County has operated sediment traps in lower Latour Creek. These traps are fitted with rock sills to prevent head cutting. These traps collect excess sediment during high flow. The sediment is removed by a local gravel contractor and sold in the aggregate market. Similar gravel harvest occurs in Wolf Lodge Creek.

The Lake Creek SAWQP was discussed earlier. This program has contracts let for application of agricultural best management practices on 2,270 acres of the 8,147 critical cropland acres in the watershed. In addition 1,135 acres have been placed in the federal Conservation Reserve Program. The SAWQP program is currently 42% implemented.

2.4.2. Pollution Control Strategies

Pollution control strategies are required for sediment and temperature in one watershed, for sediment and bacteria in another and for sediment in an additional two watersheds.

A temperature TMDL would set thermal guidelines to meet state temperature criteria. The TMDL might then assess the amount of unshaded stream within the watershed. Relationships between the percent of stream shading and the thermal input to the stream have been developed. Based on these relationships and the inventory of stream shading, riparian plantings would be allocated to achieve a percent cover goal associated with a thermal goal.

Sediment TMDLs have a less precise criteria-based goal. In this case a level of sediment reduction based on best professional judgement of hydrologists and sedimentologists would be set for each watershed requiring a TMDL. Since roads are known to be the major sediment yielding areas, the TMDL would allocate sediment load reduction based on road improvements or abandoned road obliteration. Roads located within the floodplain of streams and affecting the stream gradient would be targeted for removal. Where stream gradient had been altered for agricultural purposes, stream realignment or armoring should be explored. Stream crossings are additional locations at which forest roads are a source of sediment generation, both directly or by increased water capture. Where no longer needed these crossings should be decommissioned to remove culverts, lay back the stream bed and make the road surface an out sloped an infiltrating surface, by grading and ripping the surface. Sediment reduction can be estimated for all of these measures. The watersheds can be inventoried to select a suite of sediment reducing projects. A system of pollution credit trading might be instituted as part of the TMDL to engage the private sector in the implementation of sediment reducing projects as best management practices are currently installed today as a part of doing business in forested watersheds. Agricultural incentives could be applied to promote application of stream channel's gradient restoration or armoring on private agricultural lands.

A bacterial TMDL would require reduction of bacteria numbers in a stream through different livestock management. The TMDL would require specific percent reductions of these management actions.

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Appendix A: Fish population base data.

Stream	HUC Number	Area Electrofished (m^2)	Time Electrofished (sec)	Number of Salmonids	Number of Sculpin	Salmonid Density (fish/m^2/hr effort)	Sculpin Density (fish/m^2/hr effort)
Coeur d'Alene River	17010303 3529 - 4023	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Latour Creek[1]	17010303 3535	783	4,237	25	169	0.0271	0.1834
Baldy Creek	17010303 7535	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Larch Creek	17010303 7536	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Fourth of July[1] Creek	17010303 3534	400	850	5	59	0.0529	0.6247
Willow Creek	17010303 3531	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Thompson Creek	17010303 3530	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Wolf Lodge Creek[1]	17010303 3541	400 2,200	1,041 3,897	13 37	160 137	0.1124 0.0155	1.3833 0.0575
Marie Creek	17010303 7541	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cedar Creek[1]	17010303 3541	350	861	55	48	0.6570	0.5734
Fernan Creek[1]	17010303 3543	N.D. (150)	N.D. (801)	N.D. (6)	N.D. (0)	N.D. (0.1798)	N.D. (0.0000)
Cougar Creek[1]	17010303 3545	200	744	19	16	0.4597	0.3871
Kid Creek	17010303 3546	N.D.	N.D	N.D	N.D	N.D	N.D
North Fork Mica[1] Creek-Mica Creek	17010303 3547	200	1,500	5	4	0.0600	0.0480
Lake Creek[2]	17010303 3549	93.88*	N/A	2.61	N.D.	0.0279	N.D.

Note: 1 - data from DEQ beneficial use reconnaissance program 1993; 2 - data from Cd'A Tribe; * - calculated based on average number per 100feet (30.48m) and mean width of 10.1 feet (3.08m); ( ) - data from segment above WQL segment; N.D - no data.

Appendix B: Sediment Model Assumptions and Documentation

Sediment Model Assumptions and Documentation

Background:

Sediment is the pollutant of concern on the majority of the water quality limited streams of the Panhandle Region. The form the sediment takes is most often governed by the lithology or terrane of the region. Two major terranes dominate in northern Idaho. These are the meta-sedimentary Belt Supergroup and granitics present either in the Kaniksu batholith or in smaller intrusions as the Round Top Pluton and the Gem Stocks. In some locations Columbia River Basalt formations are important, but these tend to be to the South and West primarily on the Coeur d'Alene Reservation. Granitics weather to sandy materials with a lesser amount of pebbles or larger particle sizes. Pebbles and larger particle sizes with significant amounts of sand remain in the higher gradient stream bedload. The Belt terranes produce both silt size particles and pebbles and larger particle sizes. Silt particles are transported to low gradient reaches, while the larger sizes comprise the majority of the higher gradient stream bedload. Basalts erodes to silt size and particles similar to the Belt terranes, but the large basalt particles are less resistant, weathering to smaller particles.

Any attempt to model the sediment output of watersheds will provide, relative rather than exact, sediment yields. The model documented here attempts to account for all significant sources of sediment separately. This approach is used to identify the primary sources of sediment in a watershed. This identification of primary sources will be useful as implementation plans designed to remedy these sources are developed. The approach has the added advantage of identifying to the state of the technology all of the sources. If additional investigation indicates sources quantified as minor are not, the model input can be altered to incorporate this new information.

Model Assumptions:

Land use and sediment delivery:

RUSLE is the correct model for pasture. RUSLE accounts for production and delivery of sediment. Sediment modeled by RUSLE is fine.

WATSED covers production and delivery of sediment from forested areas. Sediment modeled by WATSED is fine and course.

Sparse and heavy forest of all age classes including seedling-sapling should be given mid range of the WATSED coefficient for the geologies, while areas not fully stocked by Forest Practices Act standards are given the upper end of the range.

WATSED coefficients can be modified within the range observed to estimate highway corridor land use and the effects of repeated wild fires.

Double burned areas have eroded significantly to the stream channel but are not now eroding; a residual sediment load in the channels is possible from previous catastophic burns.

Road sediment production and delivery:

Road erosion using the CWE approach should be limited to the 200 feet of road on either side of road crossings, not to total road mileage.

The use of the McGreer relationship between CWE score and road surface erosion is a valid estimate of road surface fines production and yield. In the case of Belt terrane, it is a conservative (overestimate) estimate.

CWE data collected for actual road fill failures and sediment delivery reflects the situation throughout the watershed. Since the great majority of road failures occur during episodic high discharge events with a 10 - 15-year return period, road failures reflect the actions of the last large event and must be divided by ten for an annualized estimate.

Fines and course loading can be estimated for stream reaches where roads encroach on the stream using estimated an erosion rate on defined model cross-section. Erosion resulting from encroachment occurs primarily during episodic high discharge events with a 10 - 15-year return period, road encroachment erosion must be divided by ten for an annualized estimate.

Failing road fill and eroding bank is composed of fines and course material. The proportions of fines and course material can be estimated from the soil series descriptions of the watershed.

Sediment Delivery:

100% delivery from forest lands estimated with WATSED coefficients

100% delivery from agricultural lands estimated with RUSLE

100% delivery from all road miles up to 200 feet from a stream crossing as estimated by the McGreer relationship.

Fines and course materials are delivered at the same rate from fill failures and from erosion resulting from road encroachment..

Model Approach:

The sediment model attempts to account for all sources of sediment by partitioning these sources into broad categories.

Land use is a primary broad category. It is treated separate from other characteristics as stream erosion and roads. Land use types are divided into agricultural, forest, urban and highways.

Agriculture may be subdivided into working farms and ranches and small ranchettes, which currently exist on subdivided agriculture land. Sediment yields from agricultural lands which receive any tillage, even on an infrequent basis are modeled with the Revised Universal Soil Loss Equation (RUSLE). Sediment yields were estimated from agricultural lands (rangeland, pasture and dry agriculture) using the Revised Universal Soil Loss Equation (RUSLE) (equation 1)(Hogan, 1998).

Equation 1: $A = (R)(K)(LS)(C)(D)$ tons per acre per year where:

: A is the average annual soil loss from sheet and rill erosion
: R is climate erosivity
: K is the soil erodibility
: LS is the slope length and steepness
: C is the cover management and
: D is the support practices.

RUSLE does not take into account bank erosion, gully erosion or scour. RUSLE applies to cropland, pasture, hayland or other land which has some vegetation improvement by tilling or seeding. Based on the soils, characteristics of the agriculture and the slope, sediment yields were developed for the agricultural lands of each watershed. RUSLE develops values which reflect the amount of sediment eroded and delivered to the active channel of the stream system annually.

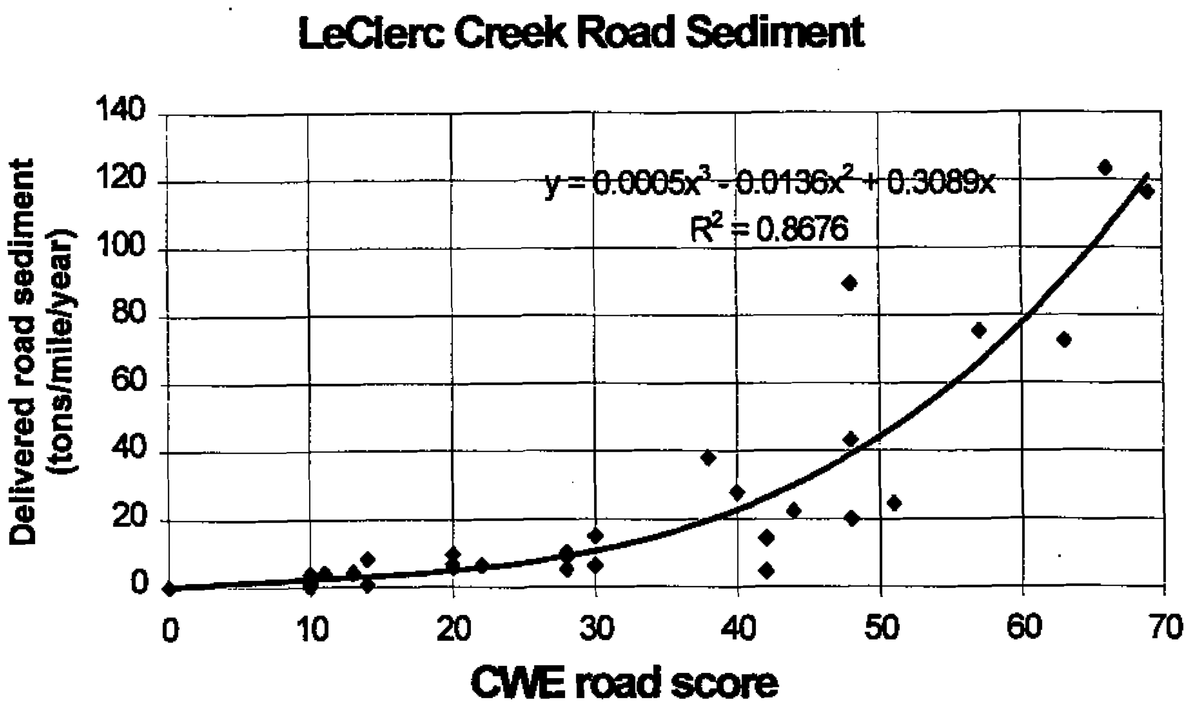
Forest lands and some land in highway rights of way are modeled using the mean export coefficients of the WATSED model for the particular geologic parent material (USFS, 1994). The values developed by WATSED are sediment eroded and delivered to the stream courses annually. Forest lands which are fully stocked with trees are treated with the median coefficient for sediment yields ascribed to that terrane. Lands not fully stocked by Idaho Forest Practices Act standards are assigned the highest coefficient of the range. Paved road rights of ways are assigned the lowest coefficient of the range. Areas which were burned by two large wild fires as delineated in IPFIRES are adjusted by a coefficient which is the difference between the highest value of the coefficient for the geologic type and the median.

All coefficients are expressed on tons per acre per year basis and are applied to the acreage of each land type developed from Geographical Information System (GIS) coverages. All land uses are displayed with estimated sediment delivery. Land use sediment delivery is totaled.

Roads are treated separately by the model. Forest haul roads are differentiated from county and private residential roads. County roads often have larger stream passage structures and are normally much wider and have gravel or pavement surfacing. Private residential roads are often limited in extent, but can have poor stream crossing structures. Sediment yields from county and private roads are modeled using a newer RUSLE model (Sandlund, 1999). Road relief, slope length, surfacing, soil material and width were the most critical factors. The sediment yield was applied only to the two hundred feet on either side of stream crossings. Failure of county and private road fills was assumed nonexistent, because such roads are often on more gentle terrain. As a consequence, road fill failures are rare.

Forest roads were modeled using data developed with the cumulative watershed effects (CWE) protocol. A watershed CWE score was used to estimate surface erosion from the road surface. Forest road sediment yield was estimated using a relationship between CWE score and the sediment yield per mile of road (Figure 1). The relationship was developed for roads on a Kaniksu granitic terrane in the LaClerc Creek watershed (McGreer, 1998). Its application to roads on Belt terrane conservatively estimates sediment yields from these systems. The watershed CWE score was used to develop a sediment tons per mile, which was multiplied by the estimated road mileage affecting the streams. In the case of roads, it was assumed that all sediment was delivered to the stream system. These are conservative estimates of actual delivery.

Figure 1: Sediment export of roads based on Cumulative Watershed Effects scores.



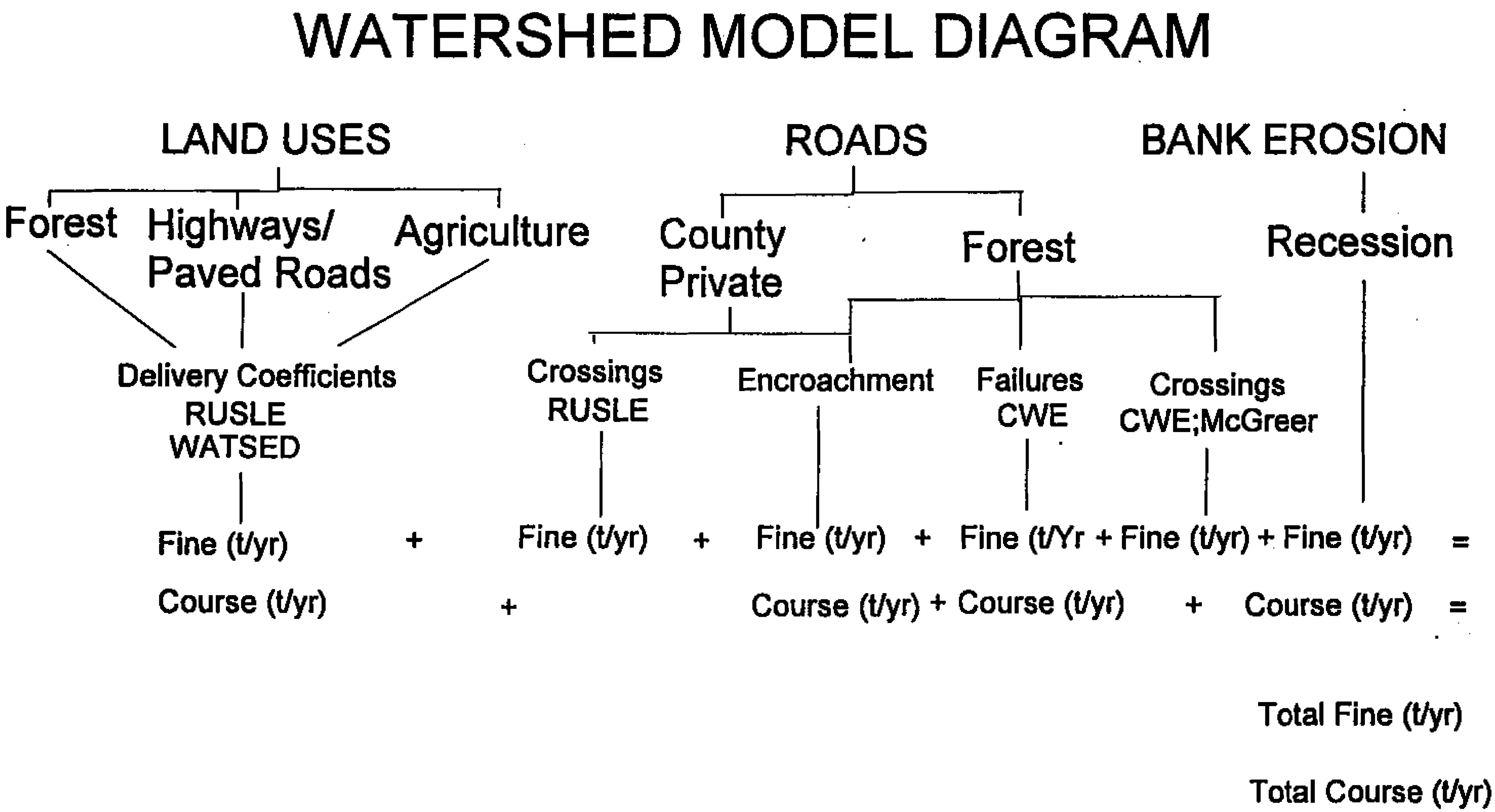
Forest road failure was estimated from actual CWE road fill failure and delivery data. These data were interpreted as primarily the result of large discharge events which occur on a 10 - 15-year return period (McClelland et. al, 1997). The estimates were annualized, by dividing the measured values by ten. The data are typically from a subset of the roads in a watershed. The sediment delivery value was scaled using a factor reflecting the watershed road mileage divided by the road mileage assessed. The sediments delivered through this mechanism contain both fine (material including and smaller than pebbles) and course material (pebbles and larger sizes). The percentages of fine and course particles were estimated using the described characteristics of the soils series found in the watershed. The weighted average of the fines and course composition of the B and C soil horizons to a depth of 36 inches was developed using the soils GIS coverage STATSGO, which contains the soils composition data provided by Soils Survey documents. The B and C horizons' composition was used because these are the strata from which forest roads are normally constructed. Based on the developed soil composition percentage and the estimated probable yield, the tons of fine and course material delivered to the streams by fill failure was calculated. This approach assumes equal delivery of fine and course materials.

Roads cause stream sedimentation by an additional mechanism. The presence of roads in the floodplain of a stream most often interferes with the streams' natural tendency to seek a steady state gradient. During high discharge periods, the constrained stream often erodes at the road bed, or if the bed is armored, erodes at the opposite bank or its bed. The erosion resulting from a road imposed gradient change results in stream sedimentation. The model assumes the roads causing gradient effects to be those within fifty (50) feet of the stream. The model then assumes one-quarter inch erosion per lineal foot of bank and bed up to three feet in height. The erosion is from the soils types in the basin with the weighted percentages of fine and course material. A bulk soil density of 2.6 g/cc is used to convert soil volume into weights in tons. The tons of fine and course material are totaled for all road segments within 50 lineal feet of the stream. The bulk of this erosion is assumed to occur during large discharge events which occur on a 10 - 15-year return period (McClelland et. al, 1997). The estimates were annualized, by dividing the measured values by ten.

The model does not consider sediment routing. The model does not attempt to estimate the erosion to stream beds and banks resulting from localized sediment deposition in the stream bed. The model does not attempt to measure the effects of additional water capture at road crossings. It is assumed, that on the balance, the additional stream power created by additional water capture over a shorter period would increase net export of sediment, even though some erosion would be caused by this watershed affect.

Where estimates of bank recession have been made along Rosgen C channels, these values are added into the watershed sediment load. The fine and course material fractions of the bank material are used to estimate fine and course material delivery.

Model Diagram:



Model Operation:

The model is a simple Excel spreadsheet model composed of four spreadsheets. Key data as acreage and percentages are entered into sheets one and two of the model. County and private road data are supplied in sheet four. The total estimated sediment from the varied sources is calculated in spreadsheet three.

Assessment of Model's Conservative Estimate:

Several conservative assumptions are made in the model construction, which cause its development of conservatively high estimations of sedimentation of the streams modeled. These assumptions are listed in the following paragraphs and a numerical assessment of the magnitude of the conservatism is assigned.

The model uses RUSLE and WATSED to develop land use sediment delivery estimates. The output values are treated as delivery to the stream. RUSLE dies assume delivery if the slope assessed is immediately up gradient from the stream system. This is not the case on the majority of the agricultural land assessed. Estimates made in the Lake Creek Sediment Study indicate that at most 25% of the erosion modeled was delivered as sediment to the stream Bauer, Golden and Pettit, 1998). A similar local estimate has not been made with WATSED, but it is likely this estimate would be 25% as well. The land use model component is 75% conservative.

The roads crossing component of the model assumes 100% delivery of fine sediment from the 200 feet on either side of a stream crossing. It is more like that some fine sediment remains in ditches. A reasonable level of delivery is 80%. The model is likely 20% conservative in this component. On Belt terrane, use of the McGreer model is conservative. Since the WATSED coefficient for Kaniksu granitic is 167% of the coefficient for Belt terrane, this factor is estimated to be 67% conservative.

Road encroachment is defined as 50 feet from the stream, primarily because this is near the resolution of commonly used mapping techniques. Roads fifty feet from streams but on side hills would not affect the stream gradient. The model is likely incorrect on encroachment 20% of the time and is conservative by this factor.

Fill failure data is developed from the actual CWE field assessments. The CWE assessment does not assess all the roads in the watershed. The failure rate data is scaled up by the factor of the roads assessed divided into the actual watershed road mileage. The roads assessed are typically those remote from the stream system, which are very unlikely to deliver sediment to the stream. The percentage of watershed roads assessed varies, but it is commonly 60% or less of the watershed roads. The model is 40% conservative in this component.

Table 1 summarizes the conservative assumptions and assesses its numerical level of over-estimation.

Table 1: Estimation of the conservative estimate of stream sedimentation provided by the model.

Model Factor	Kaniksu Granitic	Belt Supergroup
100% RUSLE and WATSED delivery	75%	75%
Crossing delivery	29%	20%
McGreer Model	0%	67%
Road encroachment at 50 feet	20%	20%
Road Failure	40%	40%
Total Assessment of Over-estimate	164%	231%

The model provides an over estimate by factors of 1.6 and 2.3 for the Kaniksu and Belt terranes, respectively. This over estimation is a built in margin of safety of 167% for Cougar and Mica Creeks and 231% for Wolf Lodge and Latour Creeks.

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Soil Fines and Stone or Cobble Content Based on Weighted Average of Soil Groups Present

Watershed	Fines (%)	Stone (%)
Wolf Lodge	50	50
Cedar	50	50
Cougar	90	10
Kidd	70	30
Mica	70	30
Latour	40	60
Fourth of July	60	40
Willow	60	40
Thompson	60	40

Appendix C: Sediment Model Data Spreadsheets

Wolf Lodge Creek Sediment Budget

Wolf Lodge Watershed Land Use

Sub-watershed	Cedar Ck	Marie Ck	Wolf Lodge Ck.
Pasture (ac)	77	23	923
Forest Land (ac)	11128	11537	15717
Unstocked forest (ac)	26.1	73.6	47.8
Highway (ac)	358	0	85
Double Fires (ac)	0	0	0

Wolf Lodge Watershed Roads

Forest roads (mi)	92.2	90.1	107.1
Ave. road density (mi/sq mi)	5.7	5	4.1
Forest road crossing freq. (#/mi)	0.2	0.1	0.4
Forest road crossing number	20	12	46
County & private road crossing number	3	0	4
CWE score	18.9	18.9	18.9
Unpaved county and private roads (mi)	5.2	0.8	5
Paved county roads (mi)	0	0	4.6
Yielding Forest roads (mi)	1.5	0.9	3.5
Yielding county and private roads (mi)	0.2	0.0	0.5
Forest road encroaching (mi)	6.3	2.5	6.3
County Road encroaching (mi)	0	0	0

Wolf Lodge Creek Sediment Yield and Export Budget from Land Use Types

Watershed	Cedar Ck	Marie Ck	olf Lodge Ck.	Yield Coeff. (tons/ac/yr)
Pasture (tons/yr)	2.3	0.7	27.7	0.03
Conifer Forest (tons/yr)(fine)	128.0	132.7	180.7	0.023
(course)	128.0	132.7	180.7	
Unstoched Forest (tons/yr)(fine)	0.4	1.0	0.6	0.027
(course)	0.4	1.0	0.6	
Highway (tons/yr)(fine)	3.4	0.0	0.8	0.019
(course)	3.4	0.0	0.8	
Double Fires (tons/yr)(fine)	0.0	0.0	0.0	0.004
(course)	0.0	0.0	0.0	
Bank erosion (tons/yr)(fine)	0.0	0.0	16.5	33 tons/year (NRCS)
(course)	0.0	0.0	16.5	
Total Yield (tons/yr)(fine)	134.0	134.4	226.4	
(course)	131.7	133.7	198.7	

County, Forest and Private Road Sediment Yield

Watershed	Cedar Ck	Marie Ck	olf Lodge Ck	Yield Coeff. (tons/mi/yr)	
Forest Roads					
Surface fine sediment (tons/yr)	13.6	8.2	31.4	9	
Road failure fines (tons/yr)*	0.7	0.0	0.1	* Uses mass failure and delivery rates developed from CWE protocol pro-rated for road mi	
Road failure course (tons/yr)*	0.7	0.0	0.0	Soil Percent Fines/Cobble^	0.243243
Encroachment fines (tons/yr)#	16.9	6.7	16.9	0.5	
Encroachment course (tons/yr)#	16.9	6.7	16.9	0.5	
County and Private Roads				^ from weighted avearge of fines and stones in soils groups	
Surface fine sediment (tons/yr)	16.6	0.0	13.6		
Road failure fines (tons/yr)	0.0	0.0	0.0		
Road failure course (tons/yr)	0.0	0.0	0.0	#Assume: one -quarter inch from three feet banks; density = 2.6 g/cc	
Encroachment fines (tons/yr)	0.0	0.0	0.0	0.020833 0.25"yr/12"	
Encroachment course (tons/yr)	0.0	0.0	0.0	48591972 !19*2*3*5280*28317cc/ft3*2.6 g/cc = g/yr	
				908000 454g/lb* 2000 lb/t	
				53.51539 t/yr/mile	
				276.1	
				204	

Wolf Lodge Watershed Sediment Export

Sub-watershed	Cedar Ck	Marie Ck	Wolf Lodge Ck.	Wolf Lodge Watershed	
Land use fines export (tons/yr)	134.0	134.4	226.4	494.8	
Land use course export (tons/yr)	131.7	133.7	198.7	464.1	
Road fines export (tons/yr)	47.9	14.9	61.9	124.6	
Road course export (tons/yr)	17.6	6.7	16.9	41.2	
Bank fines export (tons/yr)	0.0	0.0	16.5	16.5	
Bank course export (tons/yr)	0.0	0.0	16.5	16.5	
Total fines export tons/yr)	181.9	149.2	304.8	635.9	635.9
Total course export tons/yr)	149.3	140.4	232.1	521.8	521.8
				1157.6	
Natural Background	267	268	386		

Wolf Lodge Watershed County and Private Roads

Cedar Ck

name	county/pr	miles	width	grade (%)	% gravel	slope lgth	cut/fill	base mat.	oil textur	cut slope	live water	t/ac/yr	acres	tons/year
Alder Ck	county	5.2	30	3-4	5-10	500	50/50	native	silt loam	vered/sta	crosses	30	0.55	16.5
													total	16.5

Marie Ck

name	county/pr	miles	width	grade (%)	% gravel	slope lgth	cut/fill	base mat.	oil textur	cut slope	live water	t/ac/yr	acres	tons/year
Marie Ck	county	0.8	30	1	15-20	750	0/100	native	silt loam	N.A.	20-100'	5	0	0
													total	0

Wolf Lodge Ck.

name	county/pr	miles	width	grade (%)	% gravel	slope lgth	cut/fill	base mat.	oil textur	cut slope	live water	t/ac/yr	acres	tons/year
Gateway	private	0.9	20	0	5-10	500	0/100	native	silt loam	N.A.	crosses	2.7	0.28	0.8
Stella Ck	private	0.5	20	2	0	500	25/75	native	silt loam	vered/sta	none	16	0	0
Alder Ck.	county	0.8	30	3-4	5-10	500	50/50	native	silt loam	vered/sta	crosses	28	0.28	7.8
Toboggan	private	1.8	20	6	0	<500	50/50	native	velly silt lo	vered/uns	none	59	0	0
Meyer Hill	county	1	30	5-6	30	200	50/50	native	velly silt lo	vered/sta	crosses	18	0.28	5
												24.7	total	13.6

Wolf Lodge Ck. Road Paved

Cougar, Kidd and Mica Creeks Sediment Budgets
Watershed Land Use

Sub-watershed	Cougar	Kidd	Mica
Pasture (ac)	2609	1772	2606
Forest Land (ac)	7854	1887	12209
Unstocked forest (ac)	189	78	64
Highway (ac)	59.4	38	61.8
Double Fires (ac)	0	0	0

Road Data

Watershed	Cougar Ck	Kidd Ck	Mica Ck
Forest roads (mi)	50	18	40
Ave. road density (mi/sq mi)	3	3.1	1.7
Forest road crossing freq. (#/mi)	1.6	0.8	0.9
Forest road crossing number	66	10	47
County & private unpaved road crossing	0	1	2
presumed CWE score	15	10	17.8
Unpaved county and private roads (mi)	12.8	2.4	1.2
Paved county roads (mi)			
Yielding Forest roads (mi)	5	0.8	3.6
Yielding county and private roads (mi)	0	0.1	0.2
Forest road encroaching (mi)	1.9	0.3	1.6
County Road encroaching (mi)	0	0	0

Cougar, Kidd and Mica Creeks Sediment Yield and Export Budget from Land Use Types

Watershed	Cougar Ck	Kidd Ck	Mica Ck	Yield Coeff. (tons/ac/yr) Cougar Ck	Kidd Ck	Mica Ck
Pasture (tons/yr)(fine)	78.3	88.6	130.3	0.03	0.05	0.05
Conifer Forest (tons/yr)(fine)	268.6	50.2	324.8	0.038		
(course)	29.8	21.5	139.2			
Unstoched Forest (tons/yr)(fine)	9.4	3.0	2.5	0.055		
(course)	1.0	1.3	1.1			
Highway (tons/yr)(fine)	1.8	0.9	1.5	0.034		
(course)	0.2	0.4	0.6			
Double Fires (tons/yr)(fine)	0.0	0.0	0.0	0.017		174.4
(course)	0.0	0.0	0.0			
Total Yield (tons/yr)(fine)	389.1	165.9	600.0			
(course)						

County, Forest and Private Road Sediment Yield
Forest Roads

Watershed	Cougar Ck	Kidd Ck	Mica Ck
Surface fine sediment (tons/yr)	25.0	2.3	35.6
Road failure fines (tons/yr)*	38.4	0.0	2.3
Road failure cobble (tons/yr)*	4.3	0.0	1.0
Encroachment fines (tons/yr)#	9.2	1.1	6.0
Encroachment cobble (tons/yr)#	1.0	0.5	2.6
County and private roads:			
Surface fine sediment (tons/yr)	0.0	6.5	0.7
Road failure fines (tons/yr)*	0.0	0.0	0.0
Road failure cobble (tons/yr)*	0.0	0.0	0.0
Encroachment fines (tons/yr)#	0.0	0.0	0.0
Encroachment cobble (tons/yr)#	0.0	0.0	0.0

* Uses mass failure and delivery rates developed from CWE protocol pro-ratec

Yield Coeff. (tons/mi/yr)^

	Cougar Ck	Kidd Ck	Mica Ck
Yield Coeff. (tons/mi/yr)^	5	3	10
Soil Percent Fines			
Fines	0.9	0.7	0.7
Cobble	0.1	0.3	0.3

^ from weighted avearge of fines and stones in soils groups

Assume: one -quarter inch from three feet banks; density = 2.6 g/cc
0.020833 0.25"yr/12"
48591972 l19*2*3*5280**28317cc/ft3*2.6 g/cc = g/yr
908000 454g/lb* 2000 lb/t
53.51539 t/yr/mile

• Fill failure rated as zero because crossings are bridges or on flat grade.

Cougar, Kidd and Mica Creeks Watershed Sediment Export

Sub-watershed	Cougar Ck	Kidd Ck	Mica Ck
Land use fines export (tons/yr)	358.0	142.7	459.0
Land use course export (tons/yr)	31.1	23.2	140.9
Road fines export (tons/yr)	63.4	8.7	38.7
Road cobble export (tons/yr)	4.3	0.0	1.0
Bank fines export (tons/yr)	9.2	1.1	6.0
Bank cobble export (tons/yr)	1.0	0.5	2.6
Total fines export tons/yr)	430.6	152.6	503.7
Total cobble export tons/yr)	36.4	23.7	144.4
Natural Background	407.0	143.5	567.8

Cougar, Kidd and Mica Watersheds County and Private Roads

Cougar Ck

name	county/pr	miles	width	grade (%)	% gravel	slope lgth	cut/fill	base mat.	soil textu	cut slope	live water	t/ac/yr	acres	tons/year
Stand Elk	private	0.25	20	1	5-10	>500	0/100	basalt		covered/sta	none	5.4	0.61	3.2
Mdwbrook	county	0.75	30	1	75	500	0/100	native		covered/sta	none	0.8	2.72	2.2
Heine	county	1.3	30	2	50	>500	25/75	native		covered/sta	50'	5.5	4.72	26
Woodside	private	0.5	20	2	50	300	0/100	native		covered/sta	at bottom	1	1.21	1.2
No name	private	0.35	20	3	5	>500	50/50	native		uncovered/uns	none	17	0.85	14.4
Thompson	county	1.7	30	4-5	20-30	300-400	50/50	native		uncovered/uns	20-50'	14	6.18	86.5
Bunn	county	0.6	20	3-4	90	>500	50/50	native		covered/sta	<100'	0.1	1.45	0.1
Cougar Et	county	0.5	30	3-4	50	500	50/50	native		covered/sta	none	3	1.81	5.5
Clemetson	county	0.9	30	3-4	50	400	50/50	basalt		covered/sta	crosses	1.8	3.2	5.9
Stack	county	1.7	30	4-5	30	200	50/50	native		covered/sta	none	12	6.18	74.2
Cougar G.	county	1.8	30	4-5	10	400	50/50	native		covered/sta	50-100	0.1	6.54	0.6
Miller	county	1.5	30	4-5	20	500	50/50	native		uncovered/uns	none	32	5.45	174.5
Reynolds	private	0.9	20	5-6	15	400-500	50/50	native		uncovered/uns	none	41	2.18	89.45
												10.3		

Kidd Ck.

name	county/pr	miles	width	grade (%)	% gravel	slope lgth	cut/fill	base mat.	soil textu	cut slope	live water	t/ac/yr	acres	tons/year
Hull	county	0.9	30	2-3	20	>500	50/50	native		covered/sta	none	15	3.27	49.1
Weniger	county	0.6	30	5	10	>500	50/50	native		covered/sta	crosses	32	2.18	69.8
												23.5		

Mica Ck.

name	county/pr	miles	width	grade (%)	% gravel	slope lgth	cut/fill	base mat.	soil textu	cut slope	live water	t/ac/yr	acres	tons/year
Carnie	county	0.15	30	1	50	>500	0/100	basalt		covered /sta	adjacent	2.3	0.55	1.2
Sausser	private	0.75	20	1	70-80	>500	0/100	nat/basalt		covered/sta	crosses	0.7	1.81	1.3
Mica Sprs	private	0.3	20	6	90	100	50/50	nat/basalt		covered/sta	none	1	0.73	0.7
												1.3		

Latour, Baldy and Larch Creeks Sediment Budgets
Watershed Land Use

Sub-watershed	Latour Ck.	Baldy Ck.	Larch Ck.
Pasture (ac)	257	0	0
Forest Land (ac)	23181	5372	548
Unstocked forest (ac)	3855	145	0
Highway (ac)	0	0	0
Double Fires (ac)	0	0	0

Road Data

Forest roads (mi)	186.9	48.2	0.5
Ave. road density (mi/sq mi)	4.4	5.4	0.6
Road crossing freq.	0.5	1.1	0
Road crossing number	65	12	0
County and private unpaved road crossings	2	0	0
CWE score	13.3	13.3	13.3
Unpaved county and private roads (mi)	4.4	0	0
Paved county roads (mi)	0	0	0
Yielding Forest roads (mi)	4.9	0.9	0
Yielding County and Private Roads (mi)	0.2	0	0
Encroaching Forest Roads	6.3	0.4	0
Encroaching County and Private Roads (mi)	0.1	0	0

Latour, Baldy and Larch Creeks Sediment Yield and Export Budget from Land Use Types

Watershed	Latour Ck	Baldy Ck	Larch Ck	Yield Coeff. (tons/ac/yr)
Pasture (tons/yr)	5.1	0.0	0.0	0.02
Conifer Forest (tons/yr)(fine)	213.3	49.4	5.0	0.023
(course)	319.9	74.1	7.6	
Unstoched Forest (tons/yr)(fine)	41.6	1.6	0.0	0.027
(course)	62.5	2.3	0.0	
Highway (tons/yr)	0.0	0.0	0.0	0.019
Double Fires (tons/yr)	0.0	0.0	0.0	0.004
Total Yield (tons/yr)(fine)	260.0	51.0	5.0	
Total Yield (tons/yr)(course)	382.3	76.5	7.6	

County, Forest and Private Road Sediment Yield

Watershed	Latour Ck	Baldy Ck	Larch Ck	Yield Coeff. (tons/mi/yr)
Forest road				
Surface fine sediment (tons/yr)	24.6	4.5	0.0	5
Road failure fines (tons/yr)*	15.5	0.0	0.0	
Road failure cobble (tons/yr)*	23.2	0.0	0.0	
Encroachment fines (tons/yr)#	13.5	0.9	0.0	
Encroachment cobble (tons/yr)#	20.2	1.3	0.0	
County and private roads				
Surface fine sediment (tons/yr)	6.2	0.0	0.0	
Road failure fines (tons/yr)*	0.0	0.0	0.0	
Road failure cobble (tons/yr)*	0.0	0.0	0.0	
Encroachment fines (tons/yr)	0.2	0.0	0.0	
Encroachment cobble (tons/yr)	0.3	0.0	0.0	
Total fine yield (tons/yr)	60.0	5.4	0.0	
Total cobble yield (tons/yr)	43.8	1.3	0.0	

* Uses mass failure and delivery rates developed from CWE protocol pro-rated

Soil Percent Fines^

0.4	Fines
0.6	Cobble

^ from weighted avearge of fines and stones in soils groups

Assume: one -quarter inch from three feet banks; density = 2.6 g/cc

0.020833	0.25"yr/12"
48591972	l19*2*3*5280*28317cc/ft3*2.6 g/cc = g/yr
908000	454g/lb* 2000 lb/t
53.51539	t/yr/mile

* Fill failure rated as zero because crossings are bridges or on flat grade.

Latour Watershed Sediment Export

Sub-watershed	Latour Ck	Baldy Ck	Larch Ck	Latour Creek Watershed
Land use fines export (tons/yr)	260.0	51.0	5.0	316.1
Land use course export (tons/yr)	382.3	76.5	7.6	466.4
Road fines export (tons/yr)	46.3	4.5	0.0	50.9
Road cobble export (tons/yr)	23.2	0.0	0.0	23.2
Bank fines export (tons/yr)	20.5	0.9	0.0	21.4
Bank cobble export (tons/yr)	13.7	1.3	0.0	15.0
Total fines export tons/yr)	326.9	56.4	5.0	388.4
Total cobble export tons/yr)	419.3	77.8	7.6	504.6
Natural Background (tons/yr)	627.7	126.9	12.6	

Latour Ck County and Private Roads

name	county/pr	miles	width	grade (%)	% gravel	slope lgth	cut/fill	base mat.	oil textur	cut slope	live water	t/ac/yr	acres	tons/year
Latour Ck	county	3.85	30	1	10	200	25/75	native	silt loam	vered/sta	00'; crosse	4.7	0.55	2.6
Dudley Ck	county	0.5	30	1-2	10	>500	20/80	native	silt loam	vered/sta	crosses	13	0.28	3.6
													Total	6.2

Fourth of July, Willow and Thompson Creeks Sediment Budgets
Watershed Land Use

Sub-watershed	4th of July	Willow	Thompson
Pasture (ac)	1,548	453	618
Forest Land (ac)	16,193	3,386	1,868
Unstocked forest (ac)	165	36	80
Highway (ac)	336	0	0
Double Fires (ac)	906	0	0

Road Data

Forest roads (mi)	77.6	22.5	21
Ave. road density (mi/sq mi)	2.8	3.7	5.4
Road crossing freq.	1.2	1.5	2.2
Road crossing number	76	16	23
County and private unpaved road crossings	1	0	0
CWE score	20.2	24.6	17.3
Unpaved county and private roads (mi)			
Paved county roads (mi)	-	-	-
Yielding Forest roads (mi)	5.8	1.2	1.7
Yielding County and Private Roads (mi)	0.08	-	-
Encroaching Forest Roads	0.4	0.9	1.3
Encroaching County and Private Roads (mi)	0	0	0

Fourth of July, Willow and Thompson Creeks Sediment Yield and Export Budget from Land Use Types

Watershed	4th of July	Willow	Thompson	Yield Coeff. (tons/ac/yr)		
Pasture (tons/yr)(fine)	46.4	18.1	24.7	0.03	0.04	0.04
Conifer Forest (tons/yr)(fine)	223.5	46.7	25.8	0.023		
(course)	149.0	31.2	17.2			
Unstoched Forest (tons/yr)(fine)	2.7	0.6	1.3	0.027		
(course)	1.8	0.4	0.9			
Highway (tons/yr)(fine)	3.8	0.0	0.0	0.019		
(course)	2.6	0.0	0.0			
Double Fires (tons/yr)(fine)	2.2	0.0	0.0	0.004		
(course)	1.4	0.0	0.0			
Total Yield (tons/yr)(fine)	278.6	65.4	51.8			
Total Yield (tons/yr)(course)	154.8	31.5	18.0			

County, Forest and Private Road Sediment Yield

Watershed	4th of July	Willow	Thompson
Forest road			
Surface fine sediment (tons/yr)	51.8	12.1	13.9
Road failure fines (tons/yr)*	0.8	0.0	0.0
Road failure course (tons/yr)*	0.5	0.0	0.0
Encroachment fines (tons/yr)#	1.3	2.9	4.2
Encroachment course (tons/yr)#	0.9	1.9	2.8
County and private roads			
Surface fine sediment (tons/yr)	3.6	0.0	0.0
Road failure fines (tons/yr)*	0.0	0.0	0.0
Road failure course (tons/yr)*	0.0	0.0	0.0
Encroachment fines (tons/yr)#	0.3	0.0	0.0
Encroachment course (tons/yr)#	0.2	0.0	0.0
Total fine yield (tons/yr)	57.7	15.0	18.1
Total course yield (tons/yr)	1.5	1.9	2.8

Yield Coeff. (tons/mi/yr)

9	10	8	
Soil Percent Fines	from weighted avearge of fines and stones in soils grou		
0.6	0.6	0.6	Fines
0.4	0.4	0.4	Cobble

Assume: one -quarter inch from three feet banks; density = 2.6 g/cc
0.020833 0.25"yr/12"
48591972 I19*2*3*5280*28317cc/ft3*2.6 g/cc = g/yr
908000 454g/lb* 2000 lb/t
53.51539 t/yr/mile

* Uses mass failure and delivery rates developed from CWE protocol pro-ratec

* Fill failure rated as zero because crossings are bridges or on flat grade.

Fourth of July, Willow and Thompson Creeks Watershed Sediment Export

Sub-watershed	4th of July	Willow	Thompson
Land use fine export (tons/yr)	278.6	65.4	51.8
Land use course export (tons/yr)	154.8	31.5	18.0
Road fine export (tons/yr)	57.7	12.1	13.9
Road course export (tons/yr)	1.5	0.0	0.0
Bank fines export (tons/yr)	1.5	2.9	4.2
Bank course export (tons/yr)	1.0	1.9	2.8
Total fines export tons/yr)	337.9	80.4	69.9
Total course export tons/yr)	157.3	33.5	20.8
Natural Background	419.6	89.1	59.0

3.0 Total Maximum Daily Loads for the Water Quality Limited Water Bodies of the Coeur d'Alene Lake and River Sub-basin (17010303)

3.1 Wolf Lodge Creek Watershed Total Maximum Daily Load

3.1.1 Introduction

Wolf Lodge Creek and its tributaries Marie and Cedar Creeks are listed as water quality limited on the 1998 section 303(d) CWA list. The sub-basin assessment (section 2.0) indicates that Wolf Lodge Creek is impaired by excess sedimentation. The model used estimated 237 tons/year above the background sedimentation rate. However, the sediment loading of streams in the northern Rocky Mountains is not continuous nor does it occur on a yearly basis. The majority of the sediment resident in the bed and affecting the beneficial uses is loaded in large discharge events which have a return period of 10 - 15 years. The model accounts for this fact by dividing mass failure and road encroachment sediment estimates by ten. Wolf Lodge Creek could possibly have 2,370 tons of sediment resident in its bed from the 1996 flood event. This amount added to any residual sediment from the 1974 and earlier flood events. Marie Creek is listed for habitat alteration. Habitat alteration is not a characteristic, which can realistically be addressed with a TMDL. A TMDL addressing the excess sedimentation of Wolf Lodge Creek will require that sediment loads from Marie and Cedar Creek as well as its other tributaries be addressed.

The Wolf Lodge Creek watershed has the ownership pattern outlined below:

Ownership	Acreage	Percentage
Federal	32,592	82
State	386	1
Private	6,742	17
Total	39,720	100

The land use pattern has the pattern outlined below:

Land Use	Acreage	Percentage
Forest Use		
USFS	32,592	82.1
State & Private	5,382	13.5
Agriculture &		
Residential Subdivision	1,746	4.4
Total	39,720	100.0

Stream frontage on agricultural bottom lands is divided as follows:

Stream Frontage Use	Footage	Percentage
Working ranch	25,872	48.5
Ranchette	27,456	51.5
Total	53,328	100.0

3.1.2 TMDL Authority

Section 303(d)(1) of the Clean Water Act requires states to prepare a list of waters not meeting state water quality standards in spite of technology based pollution control efforts and the application of best management practices for nonpoint sources. This list must include a priority ranking "... taking into account severity of the pollution and the uses to be made of such waters." The prescribed remedy for these water quality limited waters is for states to determine the total maximum daily load (TMDL) for pollutants "... at a level necessary to implement applicable water quality standards with seasonal variations and a margin of safety ..." A margin of safety is included to account for any lack of knowledge about how limiting pollutant loads will attain water quality.

Section 303(d)(2) requires both the list and any total maximum daily loads developed by the state be submitted to the Environmental Protection Agency (EPA). The EPA is given thirty days to either approve or disapprove the state's submission. If the EPA disapproves, the agency has another thirty days to develop a list or TMDL for the state. Both the list and all TMDLs, either approved or developed by EPA, are incorporated into the state's continuing planning process as required by section 303(e).

3.1.3 Loading Capacity

The load capacity for a TMDL designed to address a sediment caused limitation to water quality is complicated by the fact that the State's water quality standard is a narrative rather than quantitative standard. In the waters of the Wolf Lodge Creek watershed, the sediment interfering with the beneficial use (cold water biota) is most likely large bedload particles. Adequate quantitative measurements of the effect of excess sediment have not been developed. Given this difficulty a sediment loading capacity for the TMDL is more difficult to develop. This TMDL and its loading capacity is based on the following premises:

: natural background levels of sedimentation are assumed to be fully supportive of the beneficial uses, cold water biota.

: the stream system has some finite yet unquantified ability to process (attenuate through export and/or deposition) a sedimentation rate greater than background rates.

: the beneficial use (cold water biota) in-stream will be fully supported when the finite yet unquantified ability of the stream system to process (attenuate) sediment is met.

: care must be taken to control factors which may interfere (fish harvest) with the quantification of beneficial use support.

The natural background sedimentation rate from the Wolf Lodge Creek Watershed is 910 tons per year. (Background sediment yield = 39,553 acres x 0.023 tons/acre/yr). This calculation assumes the entire watershed would be vegetated by coniferous forest, if undisturbed. This value is the interim loading capacity.

3.1.4 Margin of Safety

The model employed to estimate sedimentation rates has several conservative assumptions, which are documented in Section 2.0, Appendix B. Applied to the Belt terrane of the Wolf Lodge watershed, the model provides an inherit margin of safety of 231%. This is a sufficient margin of safety.

3.1.5 Appropriate Measurements of Full Beneficial Use Support

Sediment load reduction from the current level towards the interim sediment reduction goal is expected to attain an as yet unquantified sediment load at which the beneficial use (cold water biota) will attain full support. This sediment load will be recognized by the following appropriate measures of full cold water biota support:

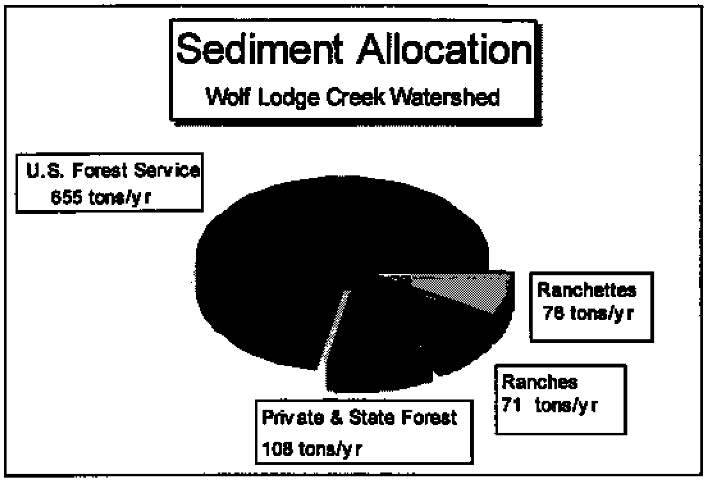
: three or more age classes of trout with one young of the year.
: trout density a reference levels (0.1-0.3 fish/yd^2/hour effort).
: presence of sculpin and tailed frogs.
: macro invertebrate biotic index score of 3.5 or greater.

When the appropriate sediment loading capacity is determined by these appropriate measures of full cold water biota support, the interim load capacity will be revised to the appropriate load capacity.

3.1.6 Sediment Load Allocation

The current estimate of the sediment load capacity of the watershed is 910 tons per year. Model estimates indicate that 40 tons (16.2%) are from agricultural land and that 217 tons (83.8%) has its origin from forest land. The sediment load allocated to the forest lands is 763 tons per year (910 t/yr x 0.838). The sediment load allocated to agricultural lands is 147 tons per year (910 t/yr x 0.162). The U.S. Forest Service is allocated 655 tons per year (763 t/yr x 0.858), while the private and State forest land is allocated 108 tons per year (763 t/yr x 0.142). The ranches along the stream are allocated 71 tons per year (147 t/yr x 0.485), while the ranchettes are allocated 76 tons per year (147 t/yr x 0.515).

Figure 1



3.1.7 Sediment Load Reduction Allocation

3.1.7.1 Current Sediment Yield from Forest and Agricultural Bottom Lands.

The current estimate of sediment yield from the watershed is 1,157 tons per year (section 2.3.2.8; table 15) It is estimated that 83.8% has its origin from forest land, while 16.2% has its origin from agricultural lands along the stream. The sediment load reduction sought from forest lands is 207 tons per year ([1,157 - 910] x 0.838). The sediment load reduction sought from agricultural lands is 40 tons per year ([1,157 - 910] x 0.162).

3.1.7.2 Forest Lands

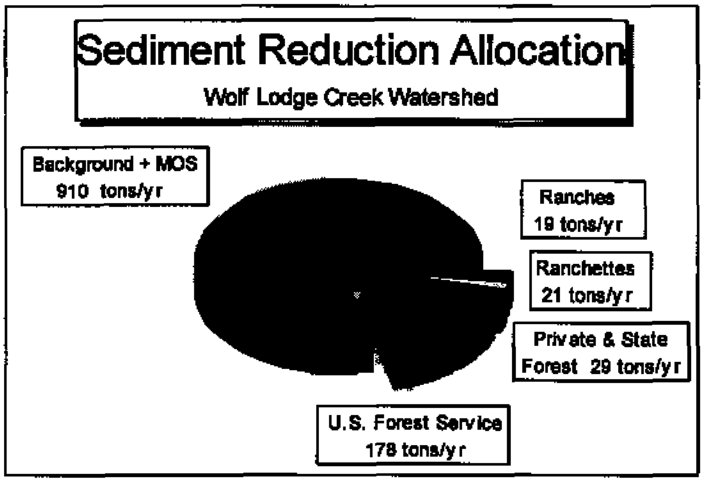
Sediment sources from forest lands are primarily associated with the road systems. Prime sediment sources are roads located in stream flood plains, road crossings of streams and erosion from road surfaces channeled directly to streams.

The U.S. Forest Service manages 85.8% of the forest lands and is allocated a sediment load reduction target of 178 tons per year (207 x 0.858) from its lands. Private and State forest owners manage 14.2% of the forest lands and are allocated a sediment load reduction target of 29 tons per year (207 x 0.142) from these lands.

3.1.7.3 Agricultural Lands

Agricultural lands or those agricultural lands converted to small ranchettes are located in the lower Marie and lower Wolf Lodge Creek areas of the watershed. Ranchettes are land holdings of a few to forty acres. The primary mechanism of sedimentation from the agricultural and converted lands is stream bank erosion. Bank erosion is the result of riparian vegetation loss and channelization on working ranch lands and ranchettes. Ranchettes are allocated a sediment load reduction of 21 tons/ year (40 x 0.515). The two ranches are allocated a sediment load reduction of 19 tons/ year (40 x 0.485).

Figure 2



3.1.8 Monitoring Provisions

In-stream monitoring of the beneficial use (cold water biota) support status during and after the sediment abatement project implementation will establish the final sediment load reduction required by the TMDL. In-stream monitoring, which will detect the thresholds values identified in section 3.1.4, will be completed every year on a randomly selected 1% of the watershed's Rosgen B and C channel types. Data will be complied after five years. The yearly increments of random testing, which sum to 5% of the stream after five years should provide a data base not biased by transit fish and macroinvertebrate population shifts. Based on this data base the beneficial use support status will be determined. Monitoring will assess stream reaches 20 times bankfull width in length. These reaches will be randomly selected from the total stream channel in B and C types until at least 5% of these channels have been assessed after five years. Identical measurements will be made in appropriate reference streams, in which beneficial uses are known to be supported.

3.1.9 Feedback Provisions

Data from which the problem assessment and TMDL for the Wolf Lodge Creek watershed were developed are often crude measurements. As more exact measurements are developed during implementation plan development or subsequent to its development these will be added to a revised TMDL as required.

When beneficial use (cold water biota) support meet the full attainment level, further sediment load reducing activities will not be required in the watershed. The interim sediment loading capacity will be replaced in a revised TMDL with the ambient sediment load. Best management practices for forest and agricultural practices will be prescribed by the revised TMDL with erosion abatement structure maintenance provisions. Regular monitoring of the beneficial use will be continued for an appropriate period to document maintenance of the full support of the beneficial use (cold water biota).

3.2. Cougar, Kidd, and Mica Creek Watersheds Sediment Total Maximum Daily Loads

3.2.1. Introduction

Cougar, Kidd, and Mica Creeks are listed as water quality limited on the 1998 section 303(d) CWA list. The sub-basin assessment (section 2.0) indicates that these creeks are impaired by excess sedimentation. Mica Creek is additionally limited by bacteria. A separate TMDL will be developed for this pollutant of Mica Creek.

Sediment model results indicate that Cougar, Kidd and Mica Creeks exceed the natural background sedimentation rate by 60, 34.3 and 80.1 tons per year, respectively. However, the sediment loading of streams in the northern Rocky Mountains is not continuous nor does it occur on a yearly basis. The majority of the sediment resident in the bed and affecting the beneficial uses is loaded in large discharge events, which have a return period of 10 - 15 years. The model accounts for this fact by dividing mass failure and road encroachment sediment estimates by ten. Cougar Creek could possibly have 600 tons of sediment resident in its bed from the 1996 flood event, while Kidd and Mica Creek would have 343 and 801 tons, repectively. These amount added to any residual sediment from the 1974 and earlier flood events.

The Cougar, Kidd and Mica Creek watersheds have the ownership pattern outlined in Table 1:

Table 1: Land ownership pattern of the Cougar and Mica Watersheds

Watershed	BLM (acres) (%)	State (acres) (%)	Private (acres) (%)
Cougar	-- (0)	423 (4)	10,229 (96)
Kidd	-- (0)	-- (0)	3,738 (100)
Mica	331 (2.2)	646 (4.3)	13,964 (93.5)

The land use pattern has the pattern outlined in Table 2a and b.

Table 2: Land use patterns of Cougar, Kidd and Mica Creeks

a) Cougar Creek

Land Use	Acreage	Percentage
State Forest	423	4.0
Private Forest	7,620	71.5
Agricultural field/pasture /ranchettes	2,609	24.5

b) Kidd Creek

Land Use	Acreage	Percentage
State Forest	0	0
Private Forest	1,965	52.6
Agricultural field/pasture /ranchettes	1,772	47.4

b) MicaCreek

Land Use	Acreage	Percentage
BLM Forest	331	2.2
State Forest	646	4.3
Private Forest	11,358	76.1
Agricultural field/pasture /ranchettes	2,606	17.4

3.2.2. TMDL Authority

Section 303(d)(1) of the Clean Water Act requires states to prepare a list of waters not meeting state water quality standards in spite of technology based pollution control efforts and the application of best management practices for nonpoint sources. This list must include a priority ranking "... taking into account severity of the pollution and the uses to be made of such waters." The prescribed remedy for these water quality limited waters is for states to determine the total maximum daily load (TMDL) for pollutants "... at a level necessary to implement applicable water quality standards with seasonal variations and a margin of safety ..." A margin of safety is included to account for any lack of knowledge about how limiting pollutant loads will attain water quality.

Section 303(d)(2) requires both the list and any total maximum daily loads developed by the state be submitted to the Environmental Protection Agency (EPA). The EPA is given thirty days to either approve or disapprove the state's submission. If the EPA disapproves, the agency has another thirty days to develop a list or TMDL for the state. Both the list and all TMDLs, either approved or developed by EPA, are incorporated into the state's continuing planning process as called for in section 303(e).

3.2.3 Loading Capacity

The load capacity of a TMDL designed to address a sediment caused limitation to water quality is complicated by the fact that the State's water quality standard is a narrative rather than quantitative criterion. In the waters of the Cougar and Mica Creeks watersheds, the sediment interfering with the beneficial use (cold water biota) is primarily moderate to fine grain sands. Quantitative measurements of the impact of excess sediment have not been developed. Given this difficulty a sediment loading capacity for the TMDL is more difficult to develop. The load capacity used in this TMDL is based on the following premises:

: background levels of sedimentation are assumed to be fully supportive of the beneficial use, cold water biota.

: the stream system has some finite yet unquantified ability to process (attenuate) a sedimentation rate greater than background rates.

: the beneficial use (cold water biota) in-stream will respond to a level of full support, which can be quantified when the finite yet unquantified ability of the stream system to process (attenuate) sediment is met.

: care must be taken to control factors which may interfere (fish harvest) with the quantification of beneficial use support.

The background sedimentation rates for Cougar, Kidd and Mica Creeks watersheds are provided in Table 3.

Table 3: Background sedimentation rate and interim loading capacity and margin of safety application

Water body	Acres	Sediment load capacity (tons/year)	Modeled sediment yield to stream (tons/yr)
Cougar	10,711	407	467.0
Kidd	3,738	142	176.3
Mica	14,941	568	648.1

The natural background sediment rates are the interim loading capacities for the three watersheds..

3.2.4. Margin of Safety

The model employed to estimate sedimentation rates has several conservative assumptions, which are documented in Section 2.0, Appendix B. Applied to the Kaniksu granetic terrane of the Cougar, Kidd and Mica watersheds, the model provides an inherit margin of safety of 164%. This is a sufficient margin of safety.

3.2.5. Appropriate Measurements of Full Beneficial Use Support

Sediment load reduction from the current level towards the interim sediment reduction goal is expected to attain an as yet unquantified sediment load at which the beneficial use (cold water biota) will attain full support. This sediment load will be recognized by the following appropriate measures of full cold water biota support:

: three or more age classes of trout with one young of the year.
: trout density at reference levels 0.1 - 0.3 trout per square meter [1].
: presence of sculpin..
: macro invertebrate biotic index score of 3.5 or greater.

When the appropriate sediment loading capacity is determined by these appropriate measures of full cold water biota support, the interim load capacity will be revised to the appropriate load capacity.

3.2.6. Sediment Load Allocation

The current estimate of allocatable sediment load capacity of the watershed is provided in table 4. The sediment loads allocated to the forest lands and to agricultural/residential lands based on the acreage values of Table 2 are provided in Table 4.

Table 4: Allocation of sediment load capacity between land uses in the Cougar, Kidd and Mica Creeks Watersheds

Water body	Sediment load allocated to Forest Lands (tons/yr)	Sediment Load allocated to agricultural/residential lands (tons/yr)
Cougar	307	100
Kidd	75	67
Mica	469	99

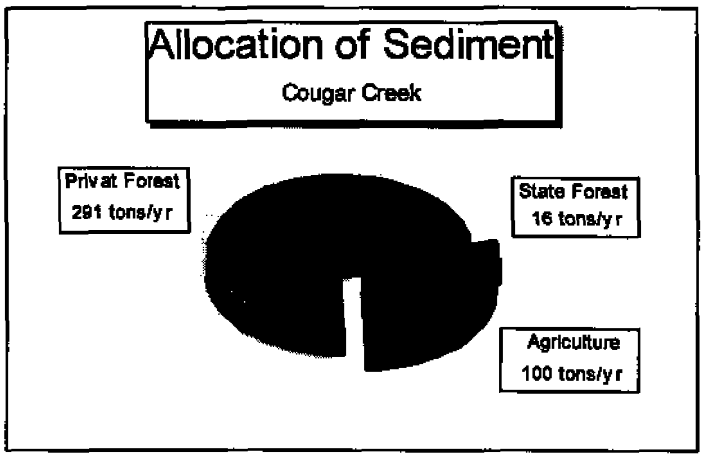
Forest Land can be further subdivided into federal, state and private forest land. The further allocation of sediment load capacity to these land uses is provided in Table 5 and figure 1 based on acreage provided in Tables 1 and 2.

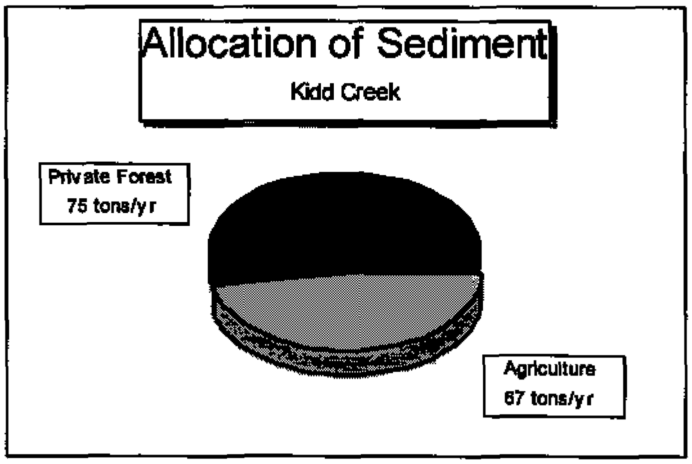
Table 5: Allocation of sediment load capacity based on subdivision of land use types.

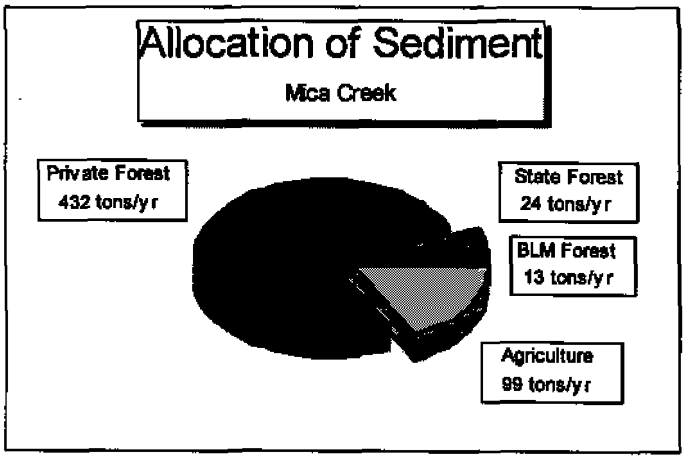
Water body	Cougar	Kidd	Mica
BLM forest (tons/yr)	-	-	13
State forest (tons/yr)	16	-	24
Private forest (tons/yr)	291	75	432
Agriculture (tons/yr)	100	67	

[1] Reference streams, Two Mouth and Trapper Creeks above development.

Figure 1







3.2.7. Sediment Load Reduction Allocation

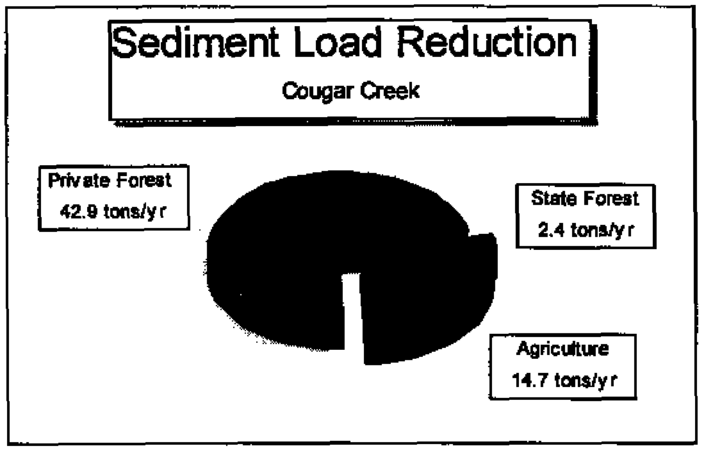
3.2.7.1. Current Sediment Yield from Forest and Agricultural Bottom Lands.

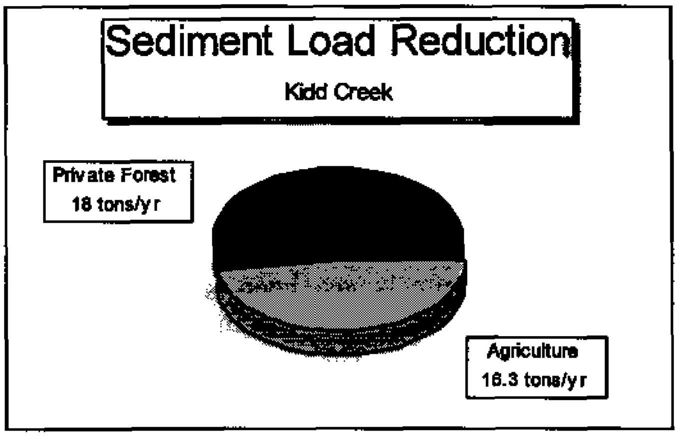
The current estimate of sediment yield from each watershed is provided in Table 3. Based on the acreage values provided in Tables 1 and 2, the sediment load reduction required of each land use is provided in Table 6 and Figure 2.

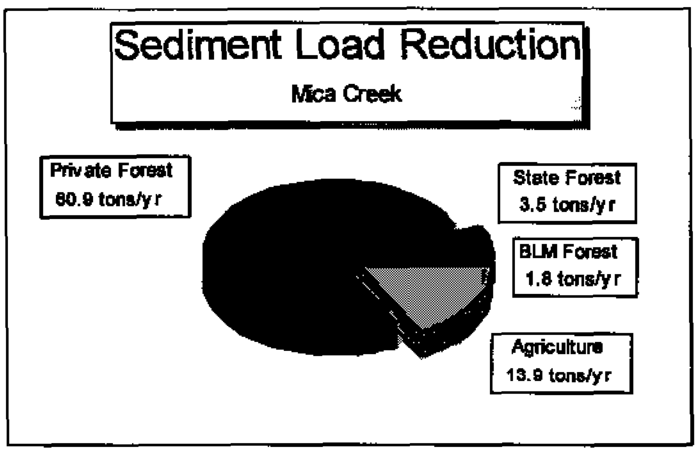
Table 6: Allocation of sediment load reduction required of each land use type.

Water body	Cougar	Kidd	Mica
BLM forest (tons/yr)	-	-	1.8
State forest (tons/yr)	2.4	-	3.5
Private forest (tons/yr)	42.9	18.0	60.9
Agriculture (tons/yr)	14.7	16.3	13.9

Figure 2


Sediment Load Reduction
Cougar Creek
Private Forest
42.9 tons/yr
State Forest
2.4 tons/yr
Agriculture
14.7 tons/yr


Sediment Load Reduction
Kidd Creek
Private Forest
18 tons/yr
Agriculture
16.3 tons/yr


Sediment Load Reduction
Mica Creek
Private Forest
60.9 tons/yr
State Forest
3.5 tons/yr
BLM Forest
1.8 tons/yr
Agriculture
13.9 tons/yr

3.2.7.2. *Forest Lands*

Sediment sources on forest lands are primarily associated with the road systems. Prime sediment sources are roads located in stream flood plains, road crossings of streams and erosion from road surfaces channeled directly to streams.

3.2.7.3. *Agricultural Lands*

Agricultural lands or those agricultural lands converted to small ranchettes are located in the Cougar Creek watershed. Ranchettes are land holdings of a few to forty acres. The primary mechanism of sedimentation from the agricultural and converted lands is stream bank erosion along these streams. Bank erosion is the result of riparian vegetation loss and channelization on working ranch lands and ranchettes.

3.2.8. *Monitoring Provisions*

In-stream monitoring of the beneficial use (cold water biota) support status during and after the sediment abatement project implementation will establish the final sediment load reduction required by the TMDL. In-stream monitoring, which will detect the thresholds values identified in section 3.2.4, will be completed every year on a randomly selected 1% of the watershed's Rosgen B and C channel types. Data will be complied after five years. The yearly increments of random testing, which sum to 5% of the stream after five years should provide a data base not biased by transit fish and macroinvertebrate population shifts. Based on this data base the beneficial use support status will be determined. Monitoring will assess stream reaches 20 times bankfull width in length. These reaches will be randomly selected from the total stream channel in B and C types until at least 5% of these channels have been assessed after five years. Identical measurements will be made in appropriate reference streams, in which beneficial uses are known to be supported.

3.2.9 *Feedback Provisions*

Data from which the problem assessment and TMDL for the Cougar, Kidd and Mica Creeks watersheds were developed are often crude measurements. As more exact measurements are developed during implementation plan development or subsequent to its development these will be added to a revised TMDL as required.

When the appropriate measurements of beneficial use (cold water biota) support status meet the full attainment level, further sediment load reducing activities will not be required in the watershed. The interim sediment loading capacity will be replaced in a revised TMDL with the ambient sediment load. Best management practices for forest and agricultural practices will be prescribed by the revised TMDL with erosion abatement structure maintenance provisions. Regular monitoring of the beneficial use will be continued for an appropriate period to document maintenance of the full support of the beneficial use (cold water biota).

3.3. Latour Creek Watershed Sediment Total Maximum Daily Loads

3.3.1 Introduction

Latour, Larch, and Baldy Creeks are listed as water quality limited on the 1998 section 303(d) CWA list for sediment. The sub-basin assessment (section 2.0) indicates that Latour Creek is impaired by excess sedimentation, while this does not appear to be the case for Baldy and Larch Creeks. A sediment TMDL addressing Latour Creek will of necessity address Baldy and Larch Creeks.

The model used estimated 126 tons/year above the background sedimentation rate. However, the sediment loading of streams in the northern Rocky Mountains is not continuous nor does it occur on a yearly basis. The majority of the sediment resident in the bed and affecting the beneficial uses is loaded in large discharge events which have a return period of 10 - 15 years. The model accounts for this fact by dividing mass failure and road encroachment sediment estimates by ten. Latour Creek could possibly have 1,260 tons of sediment resident in its bed from the 1996 flood event. This amount added to any residual sediment from the 1974 and earlier flood events.

The Latour Creek watershed has the ownership and land use pattern outlined in Table 1:

Table 1: Land use patterns of Latour Creek

Land Use	Acreage	Percentage
BLM forest	8,370	25.1 (25.3)
Forest Service forest	1,117	3.3 (3.4)
Tribal forest	1,078	3.2 (3.3)
State Forest	8,427	25.4 (25.4)
Private Forest	14,109	42.3 (42.6)
Ag/ Residential subdivision	257	0.8

Note: Values in parenthesis are percentage of forest land.

3.3.2 TMDL Authority

Section 303(d)(1) of the Clean Water Act requires states to prepare a list of waters not meeting state water quality standards in spite of technology based pollution control efforts and the application of best management practices for nonpoint sources. This list must include a priority ranking "... taking into account severity of the pollution and the uses to be made of such waters." The prescribed remedy for these water quality limited waters is for states to determine the total maximum daily load (TMDL) for pollutants "... at a level necessary to implement applicable water quality standards with seasonal variations and a margin of safety ..." A margin of safety is included to account for any lack of knowledge about how limiting pollutant loads will attain water quality.

Section 303(d)(2) requires both the list and any total maximum daily loads developed by the state be submitted to the Environmental Protection Agency (EPA). The EPA is given thirty days to either approve or disapprove the state's submission. If the EPA disapproves, the agency has another thirty days to develop a list or TMDL for the state. Both the list and all TMDLs, either approved or developed by EPA, are incorporated into the state's continuing planning process as called for in section 303(e).

3.1.3. Loading Capacity

The load capacity for a TMDL designed to address a sediment caused limitation to water quality is complicated by the fact that the State's water quality standard is a narrative rather than quantitative standard. In the waters of the Latour Creek watershed, the sediment interfering with the beneficial use (cold water biota) is most likely large bedload particles. Adequate quantitative measurements of the effect of excess sediment have not been developed. Given this difficulty a sediment loading capacity for the TMDL is more difficult to develop. This TMDL and its loading capacity is based on the following premises:

: natural background levels of sedimentation are assumed to be fully supportive of the beneficial uses, cold water biota.

: the stream system has some finite yet unquantified ability to process (attenuate through export and/or deposition) a sedimentation rate greater than background rates.

: the beneficial use (cold water biota) in-stream will be fully supported when the finite yet unquantified ability of the stream system to process (attenuate) sediment is met.

: care must be taken to control factors which may interfere (fish harvest) with the quantification of beneficial use support.

The natural background sedimentation rate from the Latour Creek Watershed is 767 tons per year. (Background sediment yield = 33,359 acres x 0.023 tons/acre/yr). This calculation assumes the entire watershed would be vegetated by coniferous forest, if undisturbed. This value is the interim loading capacity.

3.1.4. Margin of Safety

The model employed to estimate sedimentation rates has several conservative assumptions, which are documented in Section 2.0, Appendix B. Applied to the Belt terrane of the Latour watershed, the model provides an inherit margin of safety of 231%. This is a sufficient margin of safety.

Table 2: Background sedimentation rate (interim loading capacity) and modeled sediment yield of Latour Creek

Waterbody	Acres	Background sedimentation rate (tons/year) (Acres x 0.023 tons /acre/ year)	Modeled sediment yield to stream (tons/yr)
Latour	33,359	767	893

3.3.5. Appropriate Measurements of Full Beneficial Use Support

Sediment load reduction from the current level towards the interim sediment reduction goal is expected to attain an as yet unquantified sediment load at which the beneficial use (cold water biota) will attain full support. This sediment load will be recognized by the following appropriate measures of full cold water biota support:

: three or more age classes of trout with one young of the year.
: trout density a reference levels (0.1-0.3 fish/yd^2/hour effort).
: presence of sculpin and tailed frogs.
: macro invertebrate biotic index score of 3.5 or greater.

When the appropriate sediment loading capacity is determined by these appropriate measures of full cold water biota support, the interim load capacity will be revised to the appropriate load capacity.

3.3.6. Sediment Load Allocation

The current estimate of allocatable sediment load capacity of the watershed is provided in table 2. The sediment load allocated to the forest lands and to agricultural/residential lands based on the a 90% forest and 10% agriculture/ residental lands assumption (Table 3). The agriculture/ residential lands are provided a higher allocation than would be expected from the 0.8% land base in these uses. The higher assumed allocation is based on the presence of bank erosion adjacent to these properties.

Table 3: Allocation of sediment load capacity between land uses in the Latour Creek Watershed

Waterbody	Sediment load allocated to Forest Lands (tons/yr)	Sediment Load allocated to agricultural / residential lands (tons/yr)
Latour	690	77

Forest Land can be further subdivided into Forest Service, BLM, State, Tribal and private forest land. Stream bottom pasture land is completely divided into residential (ranchette) lands. The further allocation of sediment load capacity to these land uses is provided in Table 4 and figure 1 based on acreages provided in Tables 1.

Table 4: Allocation of sediment load capacity based on subdivision of land use types.

Waterbody	Latour
Forest Service (tons/yr)	23
BLM (tons/yr)	175
Tribe (tons/yr)	23
State (tons/yr)	175
Private forest (tons/yr)	294
Ag / residential (tons/yr)	77

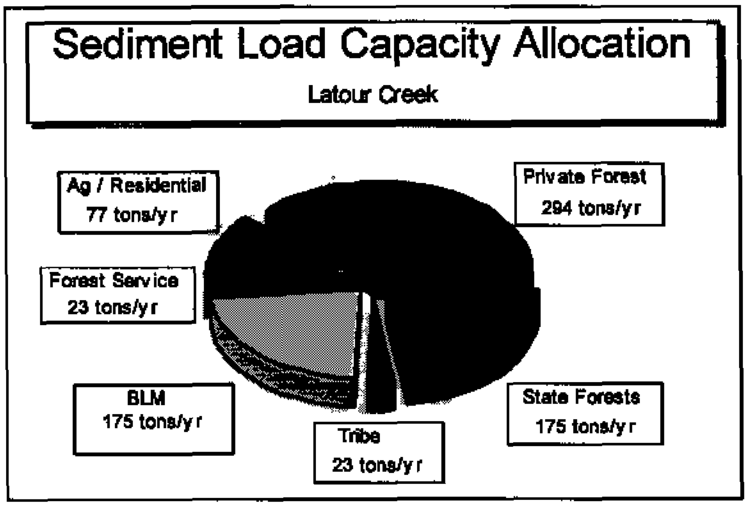


Figure 1

3.3.7. Sediment Load Reduction Allocation

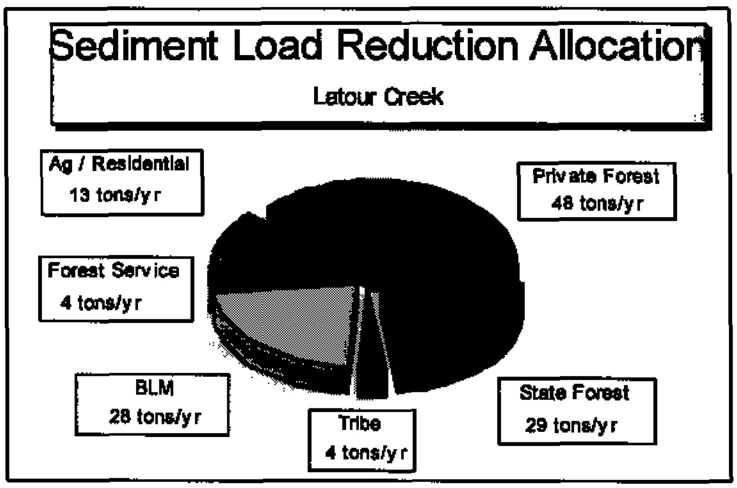
3.3.7.1. Current Sediment Yield from Forest and Agricultural Bottom Lands.

The current estimate of sediment yield for the watershed is provided in Table 2. The sediment reduction required is 126 tons per year (893 t/yr - 767 t/yr). Based on the acreage percentages provided in Tables 1, the sediment load reduction required of forest lands is 113 tons per year (126 t/yr * 0.9) and 13 tons per year (126 t/yr * 0.1) from agriculture land. The sediment reduction required of each owner group is provided in table 5 and figure 2.

Table 5: Allocation of sediment load reduction required of each land use type.

Waterbody	Cougar
Forest Service (tons/yr)	4
BLM (tons/yr)	28
Tribe (tons/yr	4
State forest (tons/yr)	29
Private forest (tons/yr)	48
Ag / residential (tons/yr)	13

Figure 2



3.3.7.2. Forest Lands

Sediment sources from forest lands are primarily associated with the road systems. Prime sediment sources are roads located in stream flood plains, road crossings of streams and erosion from road surfaces channeled directly to streams.

3.3.7.3. Agricultural Lands

Agricultural lands converted to small ranchettes are located in the Latour Creek watershed. Ranchettes are land holdings of a few to forty acres. The primary mechanism of sedimentation from the agricultural and converted lands is stream bank erosion along these streams. Bank erosion is the result of riparian vegetation loss and channelization on working ranch lands and ranchettes.

3.3.8. Monitoring Provisions

In-stream monitoring of the beneficial use (cold water biota) support status during and after the sediment abatement project implementation will establish the final sediment load reduction required by the TMDL. In-stream monitoring, which will detect the thresholds values identified in section 3.1.4, will be completed every year on a randomly selected 1% of the watershed's Rosgen B and C channel types. Data will be complied after five years. The yearly increments of random testing, which sum to 5% of the stream after five years should provide a data base not biased by transit fish and macroinvertebrate population shifts. Based on this data base the beneficial use support status will be determined. Monitoring will assess stream reaches 20 times bankfull width in length. These reaches will be randomly selected from the total stream channel in B and C types until at least 5% of these channels have been assessed after five years. Identical measurements will be made in appropriate reference streams, in which beneficial uses are known to be supported.

3.1.9. Feedback Provisions

Data from which the problem assessment and TMDL for the Latour Creek watershed were developed are often crude measurements. As more exact measurements are developed during implementation plan development or subsequent to its development these will be added to a revised TMDL as required.

When beneficial use (cold water biota) support meet the full attainment level, further sediment load reducing activities will not be required in the watershed. The interim sediment loading capacity will be replaced in a revised TMDL with the ambient sediment load. Best management practices for forest and agricultural practices will be prescribed by the revised TMDL with erosion abatement structure maintenance provisions. Regular monitoring of the beneficial use will be continued for an appropriate period to document maintenance of the full support of the beneficial use (cold water biota).

3.4 Mica Creek Watershed Bacteria Total Maximum Daily Load

3.4.1 Introduction

Mica Creek and its North Fork exceed the current fecal coliform bacteria standard for the designated use secondary contact recreation (Table 1). The current standard is a geometric mean of 200 fecal coliform per 100 ml of water over a thirty-day period. The proposed *Escherichia coli* (E-coli) standard for recreational use will be a geometric mean over a thirty-day period of 126 E-coli per 100 ml water. The TMDL is written for both standards in the event it changes in the next year.

Table 1: Fecal and E coli form bacteria from two locations on Mica Creek

Date	Mica Creek FC	Mica Creek EC	NF Mica Creek FC	NF Mica Creek EC
7/23/99	5100	2900	400	180
7/23/99		1300		200
7/27/99	570	150	600	130
7/30/99	730	630	500	380
8/4/99	800	220	720	190
8/24/99	570	300	600	300
Geometric Mean	993	535	553	216

There are no point sources discharging bacteria to Mica Creek. Potential sources of bacteria to Mica Creek are residences and grazing animals. Seven residences are located along the creek. It is unlikely that these few residences are the source of the bacteria. Three ranches and one ranchette graze livestock along the stream. These grazing animals and particularly the cattle associated with the three ranches are the likely source of the observed bacteria exceedence.

3.4.2 TMDL Authority

Section 303(d)(1) of the Clean Water Act requires states to prepare a list of waters not meeting state water quality standards in spite of technology-based pollution control efforts and best management practices applied to nonpoint sources. This list must include a priority ranking "... taking into account severity of the pollution and the uses to be made of such waters." The prescribed remedy for these water quality limited waters are for states to determine the total maximum daily load (TMDL) for pollutants "... at a level necessary to implement applicable water quality standards with seasonal variations and a margin of safety ..." A margin of safety is included to account for any lack of knowledge about how limiting pollutant loads will attain water quality.

Section 303(d)(2) requires both the list and any total maximum daily loads developed by the state be submitted to the Environmental Protection Agency (EPA). The EPA is given thirty days to either approve or disapprove the state's submission. If the EPA disapproves, the agency has another thirty days to develop a list or TMDL for the state. Both the list and all TMDLs, either approved or developed by EPA, are incorporated into the state's continuing planning process as called for in section 303(e).

3.4.3 Loading Capacity

Measured discharge on Mica Creek was 2.5 cubic feet per second (cfs), while the North Fork was measured at 1.7 cfs. These are the only measurements available. These measurements were made during August 1995. For purposes of calculation the loading capacity a mean summer discharge of 4 cfs and 2.7 cfs were assumed for Mica Creek and its North Fork, respectively. These are conservatively high summer discharge estimates.

The loading capacity was based on the most stringent chronic standards, 200 fcu/ 100 ml for fecal coliform, the current secondary contact recreation standard (IDAPA 16.01.02.250.01.b.iii) and 126 ecu/100ml for E-coli, the proposed recreational use standard. Use of these standards employs the most conservative case for load capacity calculation. Load capacity for fecal coliform and E-coli are provided in Table 2. The mathematical calculations are provided in Appendix A.

Table 2: Loading Capacity and Loading Capacity with 20% Margin of Safety Applied

Stream	fcu loading capacity (number/d)	ecu loading capacity (umber/d)	fcu loading capacity - MOS* (number/d)	ecu loading capacity - MOS* (number/d)
Mica Creek	1.96×10^{10}	1.23×10^{10}	1.57×10^{10}	9.87×10^{9}
NF Mica Creek	1.32×10^{10}	8.32×10^{9}	1.06×10^{10}	6.66×10^{9}

* Note: MOS applied is 20%, which for these numbers would range from 1.6 to 3.9 billion coliform units.

3.4.4 Margins of Safety

Three margins of safety are constructed into the TMDL. This is necessary because a very limited amount of discharge and coliform data is available on which to base the TMDL. Since only a single set of discharge values are available the assumed flow is placed at a high summer flow for a stream likely able to support secondary contact activities. The chronic standards are employed to construct the loading capacity. This is the most stringent standards of the three available. A twenty percent margin of safety is removed from the loading capacities in order to account for the limited number of coliform observations.

3.4.5 Current Coliform Loads

Current coliform loads were developed using the geometric mean and the assumed flows provided in section 3.4.1 and 3.4.3. Current loads were estimated with the identical method as the loading capacity except the geometric means of the observed values were used (Table 3; Appendix A).

Table 3: Estimates of current coliform bacteria loads of Mica Creek and North Fork Mica Creek

Stream	Fecal Coliform/d	E coli/d
Mica Creek	9.72×10^{10}	5.41×10^{10}
NF Mica Creek	3.53×10^{10}	1.43×10^{10}

3.4.6 Coliform Reductions Required

The coliform reductions required are provided in Table 4. These values are the subtraction of the loading capacity modified for the margin of safety (Table 2) from the estimates of current coliform loads (Table 3). The resulting numbers are very large and difficult to grasp. For this reason the percentage coliform reduction is expressed.

Table 4: Estimated coliform reductions for Mica Creek and North Fork Mica Creek and the percent reductions required

Stream	Fecal Coliform/d Percent Reduction	E coli/d Percent Reduction
Mica Creek	8.15×10^{10} (83.9%)	4.42×10^{10} (81.8%)
NF Mica Creek	2.47×10^{10} (70.1%)	7.64×10^{9} (53.3%)

Bacterial contamination is from nonpoint sources. The majority of the bacterial contamination is most likely from grazing animals. The majority of these animals are on three ranches. One ranch is on the North Fork Mica Creek while the other two are below the North Fork - South Fork confluence. The entire allocation for the North Fork and the reduction required for the North Fork can be ascribed to the ranch to the west of Highway 95. The additional reductions required for Mica Creek would come from the ranches to the east of the highway and the small amount of stock on the single ranchette.

3.3.7 Monitoring Provisions

In-stream monitoring of the fecal coliform and E coli will be conducted after bacteria abatement project implementation. In-stream monitoring which should detect the bacteria reductions required in section 3.4.6 will be completed every two years at points of compliance at the Loff's

Bay Road Bridge and the Highway 95 Bridge. Two sample sets will be collected during the low discharge (summer) period. A sampling set will include at a minimum five integrated samples over a two week period. From these data geometric means can be developed.

3.4.8 Feedback Provisions

Data, from which the problem assessment and Mica Creek bacteria TMDL was developed, are often limited measurements. If more measurements are made during implementation plan development or subsequently to its development. These data will be used to revised the TMDL as required.

When the coliform levels meet the appropriate standard and bacteria reduction, further bacteria load reducing activities will not be required in the watershed. Best management practices for agricultural practices will be prescribed by the revised TMDL with structure maintenance provisions. Regular monitoring of the bacteria levels will be continued for an appropriate period to establish maintenance of the full support of the coliform standard.

Appendix A

4. Draft Response to Comments on the Coeur d'Alene Lake and River Sub-basin Assessment and Wolf Lodge, Cougar, Kidd, Mica and Latour Creek TMDLs.

4.1. Introduction

Three letters of comment on the sub-basin assessment and TMDLS have been received. These letters contained twenty-three substantive and distinctive comments. In addition to the comments, the sediment modeling technical advisory group met to discuss the sediment model and to discuss any comment made concerning the sediment model. The sediment model advisory group is made up of hydrologist and sedimentologists from state and federal agencies (USFS, BLM, IDL, SCC, IDFG), an environmental group and the timber industry. The comments are addressed in the section following with the comment expressed, the source of the comment and the response to that comment. Responses included changes in the assessment and the TMDLs. If a comment was not accepted, the reason the comment was disregarded is expressed.

4.2. Substantive Comments and Response

Comment 1: The acute salmonid sight feeding turbidity standard was misstated in the sub-basin assessment, Table 3 and misapplied to Lake Creek. The text on Lake Creek indicates that this water body is not limited by sediment.

Comment from: Nickolas Bugosh, Division of Environmental Quality Lewistion Field Office

Response 1: The acute salmonid sight feeding turbidity standard was misstated in Table 3. This error has been corrected to make clear that both the acute and chronic standards are applied in reference to a measured appropriate background measurement. The Lake Creek section has been clarified to state that the turbidity increases reported are referenced to an upstream background site in the work of Bauer, Golden and Pettit (1998). Following these clarifications, it is still the conclusion of the sub-basin assessment that Lake Creek is water quality limited and requires a TMDL.

Comment 2: RUSLE was used to model the sediment yield of dirt and gravel roads. The comment expresses the opinion that this is an improper application of RUSLE, because RUSLE has not been verified for roads.

Comment from: Nickolas Bugosh

Response 2: On the advice of the State DEQ office and the local Natural Resource Conservation Service (NRCS), RUSLE was used to model dirt and gravel roads which are county and private roads. The newer versions of RUSLE are capable of modeling roads composed of native soils and covered with gravel. These roads should be in areas where NRCS Soils Surveys are complete. The model has been verified for this use. The sediment technical advisory group discussed this issue and was in agreement that it was appropriate to model county and private roads where Soil Surveys existed with the RUSLE model.

Comment 3: The margin of safety (MOS) discussion section in the TMDLs is not clear. It reads as if the MOS should be added to the natural background rate of sedimentation, even though it is subtracted in the tables. In addition the need for a 10% margin of safety was questioned. The comment noted that the model used to estimate sediment was repeatedly conservative in its assumptions. The comment suggested the conservatism of each assumption be quantified. It was suggested that this is an adequate MOS as specified by EPA TMDL guidance (EPA, April 1991).

Comment from: Nickolas Bugosh

Response 3: Based on this comment the 10% margin of safety was dropped. As a part of the revised Sediment Model Assumptions and Documentation section (Appendix B), the conservatism of each assumption was assessed as a percentage. These percentages were then added. For the Kaniksu granitic terrane, the model is 164% conservative; for the Belt Meta-sedimentary terrane, the model is 231% conservative. These percentages have been applied in the TMDLS as the MOS, dependent on the terrane type of the watershed in question.

Comment 4: The basic premise of the Wolf Lodge TMDL is weak because the temporal and spacial variability of fish and macro invertebrates make it difficult to measure a substantive improvement. The comment notes that no one to one or other relationship between biotic populations and sediment has been found. The monitoring plan should calculate sample size based on coefficients of variability. Reference streams cannot be used because of this variability. The comment suggests that particle size distribution and intergravel dissolved oxygen measurements would bolster the monitoring plan.

Comment from: Robert Sampson, Natural Resources Conservation Service, Boise Office

Response 4: The monitoring plan has been revised in the TMDLs to address temporal biotic variability. The 5% of the stream reach will be monitored, 1% per year over a five years period. This approach should address temporal variability of the biota. Monitoring by necessity will be limited to the low flow period during the warm summer months. This fact reduces seasonal variability.

The comment makes an excellent point. There is no one to one or other relationship between biota and sedimentation. This is the reason the approach is taken in the TMDLs. Despite all the issues of temporal and spacial variability, assessment of Beneficial Use Reconnaissance, Fish and Game, Forest Service and University of Idaho data on fish and macro invertebrates in the nearby North Fork Coeur d'Alene River watershed indicates a pattern (IDEQ, 1999a) Reference (low impact) streams consistently have a trout population of 0.1-0.3 fish/ m^2/hour effort electrofishing. This is a broad range 10 - 30 fish per 100 square meters per hour effort electrofishing. The reference streams assessed are of varying size. A similar range is found in reference streams in the Priest Lake watershed. Densities an order to two orders of magnitude lower are found on streams with sedimentation impacts. The use of qualitative indicators as young of the year, age classes and presence of other vertebrates rounds out the definition of full support.

The suggestion that coefficients of variability be developed and used to develop sample size is a good suggestion. Unfortunately, the current data base on any single watershed is insufficient to complete a sample size analysis. The TMDL implementation plans should specify that this analysis is completed as additional biotic community data is collected. The suggestion that particle size and intergravel dissolved oxygen would improve the monitoring plan is erroneous. Particle size is only very tangentially related to beneficial use support, while intergravel dissolved oxygen depletion is not an issue in any of the watersheds for which TMDLs were developed. Pool filling by cobble and course sand are the likely impacts to fish (IDEQ, 1999b), while the impact to macro invertebrates is less clear. Neither parameter can be directly related to the support status of the biotic communities.

Comment 5: The base sedimentation coefficient used are too low. The sedimentation rates used grouped around 15 (Belt) and 25 (Kaniksu granitic) tons per year. The comment cites considerable information to indicate that 60 - 100 tons per year is a more appropriate number.

Comment from: Robert Sampson

Response 5: The model uses the sediment yield coefficients of the WATSED model. This issue was raised with the sediment technical advisory group. The agency and private hydrologists on the group were satisfied with the WATSED values. The only explanation offered was that the values cited by the comment were those for total solids yield; sediment as well as dissolved solids. The WATSED values are actual measured values, which are calibrated to local conditions on the Clearwater Forest to the south. On the advice of the technical group the WATSED coefficients have been retained.

Comment 6: Road erosion is the primary source of sediment. The comment suggests county and private roads should have been considered.

Comment from: Robert Sampson

Response 6: The reviewer did not have benefit of the sub-basin assessment as the Wolf Lodge TMDL was reviewed and comment developed. The county and private roads were considered. Where these came into contact with the stream system, either as at a stream crossing or encroaching, their impact was modeled. The CWE assessment accounted for any mass failures from county and private roads.

Comment 7: The level of sedimentation attributable to bank erosion from agricultural lands along Wolf Lodge Creek is an order of magnitude too high. The correct values are around 30 (actually 33) tons per year.

Comment from: Robert Sampson

Response 7: The sediment delivery from banks placed in the earlier drafts of the TMDL were based on an earlier version of the model which generated higher sediment delivery rates and on the agricultural acreage. The model has been corrected and the bank erosion estimates supplied by the NRCS incorporated. The percentages assigned to agriculture and residences are now based on the estimated sediment delivery from these sources.

Comment 8: The reviewer after viewing the stream reach covering agricultural lands did not find bed load to be a problem in the stream. He did not find the statement on bed load impacts to be supported.

Comment from: Robert Sampson

Response 8: The reviewer was supplied with the TMDL alone and did not have benefit of the sub-basin assessment where many of these issues were discussed. The Coeur d'Alene Mountains are deeply dissected having relative long lower gradient valleys, which at their heads are very steep. The Wolf Lodge Valley is a remnant lake bed of an earlier Coeur d'Alene Lake. The result is that the agricultural lands are along a stream of fairly low gradient. Bed load deposition and interference with biota by this mechanism occur above this reach. The agricultural reaches of Wolf Lodge Creek and especially the spawning reach immediately above Interstate 90 are more likely affected by fine sediment from bank erosion.

Comment 9: Timber management is described as moderately intense with dense road development (p.5). The assessment should have a timber harvest inventory of the listed watersheds.

Comment from: Mike Mihelich, Kootenai Environmental Alliance

Response 9: The description in the cultural impacts section was generalized to the entire sub-basin. The comment is correct Wolf Lodge and Cedar Creeks have received heavy levels of timber harvest and road development. This change has been made in the text. It was not deemed necessary to develop a harvest history for each listed watershed. These data are imbedded in the CDASTDS (USFS) and Idaho Department of Lands (IDL) geographic information system (GIS) vegetation coverages. The purpose of the assessment, models and resulting TMDLs was to address sediment not clearcuts. The Horizon Environmental Impact Statement information quoted was more than ten years old, while the GIS coverages are updated on a constant basis.

Comment 10: Direct hill slope erosion from harvested lands is much higher than the values assigned. A Geomax report of 1988 indicates higher hill slope erosion. Water yield caused sedimentation is not addressed. The fishery in the watersheds has declined in recent years.

Comment from: Mike Mihelich

Response 10: The expert group assembled to advise in model development by consensus of those present believe the WATSED sediment yield coefficients, which are based on actual watershed measurements of sediment yield reflect the sediment yield of hill slopes after various land uses. The Geomax estimations sited are based on assumptions of water and sediment yield not on actual measurements. The Geomax estimates were made for Marie Creek are ten years old and prior to the harvest which arose from Horizon. When these estimates were made, the cutting was confined to the ridges. Current GIS data indicates the same situation exists in the Marie Creek watershed.

We agree that harvest increases flow. The existing literature indicates it is the base flow that is increased. Flow increases during high discharge periods are better associated with an increase in the stream capture area at stream road crossings. In any case no quantitative relationship between increased flow or "compression" of discharge events and sediment yield was identified by the expert group. Without a relationship quantitative modeling is not possible. The model does identify road crossings, which could be addressed in an implementation plan for road sediment, road failure and water capture.

Comment 11: Description of the fishery in the Coeur d'Alene River above Cataldo is questioned.

Comment from: Mike Mihelich

Response 11: The cutthroat trout and chinook salmon fishery of the upper segments of the Coeur d'Alene River is well known to Idaho Fish and Game and local fisherman. The large river BURP results indicate the health of the fishery. Unpublished expert witness reports from the metals natural resource damage case indicates 12,000 fish per mile in these segments.

Comment 12: RASI data for Skookum Creek should be applied to Wolf Lodge and Marie Creeks.

Comment from: Mike Mihelich

Response 12: Skookum Creek is a tributary to the Little North Fork Coeur d'Alene River. Riffle armor stability (RASI) data for this and several other water bodies in the North Fork Coeur d'Alene River has been assessed in the North Fork Coeur d'Alene River Sub-basin Assessment (17010301). High RASI values indicate stream bed stability, but are distinctive to the watershed where it is collected. The Skookum Creek data would not properly be extrapolated to Wolf Lodge Creek.

Comment 13: Residual pool volume data from the Horizon EIS should be considered.

Comment from: Mike Mihelich

Response 13: Residual pool volume data, where it is available from recent BURP surveys is assessed. The Horizon data is more than ten years old. Since it was developed, a major sediment loading event, the 1996 rain on snow event, and two channel forming flows, 1997 and 1999 discharges have occurred. Residual pool volume data of ten years ago plus is likely not indicative of in stream conditions, especially after the channel forming runoffs of 1997 and 1999.

Comment 14: Simply addressing the roads in Wolf Lodge Creek will not address sediment problems.

Comment from: Mike Mihelich

Response 14: We agree that timber harvest activities have impacted Wolf Lodge and Marie Creeks. The sediment technical advisory group identified only quantitative relationships between road features and sediment. The model used points back to the road features. Implementation of the TMDL will be outlined in an implementation plan. The TMDL does not in any way encumber the solutions in an implementation plan. Although the model points to roads and road impacts, logging cessation is not in any way ruled out by the TMDL. Such decisions are not appropriate for the load allocation.

Comment 15: Several comments refer to the use of the model, WATSED and its shortcomings. Comments speak to inadequate documentation of WATSED.

Comment from: Mike Mihelich

Response 15: The model assumptions and documentation (Appendix B) make it very clear that WATSED is not used to model sediment. It is made clear the WATSED sediment yield coefficients, both mean and range are used to model sediment from forest land use. The model is designed to look at the spectrum of land use, road impacts and stream bank erosion. It uses several data and model inputs to achieve this end.

The model does account for episodic sediment loading both as measured road bed failures and estimated encroaching roads sediment generation. The model does separate fine and course sediment yield to the streams. An estimation of the conservatism of the model is made in the model assumptions and documentation (Appendix B). Applied on the Belt terrane, the model is estimated to be 231% conservative.

Comment 16: The applied model underestimates sediment yield from harvested land and the amount of non-stocked land in the Wolf Lodge Creek watershed.

Comment from: Mike Mihelich

Response 16: As stated earlier, the model is driven by inputs from Forest Service and IDL GIS data bases. These data bases are made current on a regular basis. The source of the comment information is 5 - 10 years old and most likely out of date. As originally applied, all clearcut lands younger than ten years were given a higher sediment yield rate. The sediment technical advisory group identified this approach as in error and indicated that only non-stocked stands should have the higher coefficient applied.

Comment 17: The comment is addressed to section 2.4.1; Pollution Control Efforts to Date. The comment indicates that addressing roads alone will not recover Wolf Lodge Creek. The comment refers back to the arguments made earlier concerning flow.

Comment from: Mike Mihelich

Response 17: The section simply lists the pollution control measures put in place to date. Among these is road crossing and road obliteration. Comments about flow have been addressed earlier. The comment wants sedimentation associated with flows addressed. The model addresses sediment that can be addressed through quantitative measurements. No measured relationship has been identified for flow and sedimentation.

Comment 18: Similar comment to comment 17 made concerning section 2.4.2.; Pollution Control Strategies. The comment disagrees with a pollution credit trading system to address road problems.

Comment from: Mike Mihelich

Response 18: The section simply lays out approaches, but is not intended to exclude any approach to abating sedimentation. A TMDL implementation plan could identify harvest cessation as an approach on some or all of the watershed. A conflict in points of views is apparent between the sediment technical group and the individual making the comment. The group clearly believes roads are the major source of sediment, while clear cuts are believed by the individual commenting to be the major source of sediment. As the TMDL development agency, DEQ must base models on quantities of sediment loading. No measured relationship between sediment loading and flow is offered in the comment. The model depends on measured sediment yield rates, measured fine sediment yield from roads, measured road bed failures and delivery and measured encroaching road beds.

The individual commenting must also keep in mind that sediment is not delivered in large amounts to the stream monthly or even annually, but in episodic events, which recur every 10 - 15 years. Actual measurements must be annualized in order to develop a sediment load in tons per year. This does not mean the load from these episodes does not influence the beneficial uses after one year. It is in the bed and affecting uses for a number of years. The TMDLs make this point and provide estimates of how much material might be in the bed from the most recent (1996) large loading event.

Comment 19: The Clean Water Acts interim goal of protection of fish will not be met.

Comment from: Mike Mihelich

Response 19: The TMDL sets full support of the cold water biota as the goal. It defines full support in terms of age class distribution of trout, trout density, presence of other key vertebrates and a macro invertebrate index greater than 3.5. Since the amount of sediment impacting cold water biota has not been quantified for any stream and not for these streams this appears the most conservative approach to the state.

Comment 20: Timber sales are not addressed as point discharges.

Comment from: Mike Mihelich

Comment 20: This is currently a draft regulation. It is unclear whether it will be promulgated. For this reason it has not been addressed.

Comment 21: The comment disagrees with the assumptions stated on page 2 of the Wolf Lodge TMDL.

Comment from: Mike Mihelich

Response 21: The assumptions are 1)biota are fully supported at background levels of sedimentation; 2) the stream has some finite level of sedimentation above background at which the biota is fully supported; 3) the biota will respond to a level of full support when that as yet non-quantified level of sedimentation is met. The state, respectfully, believes these assumptions to be correct.

Comment 22: The comment disagrees with the background level of sedimentation estimated for the Wolf Lodge Creek watershed citing problems with the WATSED model.

Comment from: Mike Mihelich

Response 22: The background estimation is not based on WATSED, but on the sediment yield coefficient from WATSED, which is based on measured values. The estimate is clearly identified as the acreage of the watershed multiplied by the mean sediment yield coefficient for the Belt meta-sedimentary terrane type. The estimate assumes a totally forested, non-roaded watershed.

Comment 23: The comment indicates that the Forest Service uses feedback management approaches and that the reviewer has no faith in such approaches.

Comment from: Mike Mihelich

Response 23: As reviewed earlier, clear measures of full support of the beneficial use cold water biota are defined. These measures are based on reference streams primarily in the upper part of the North Fork Coeur d'Alene River watershed. Except for wild fires during the early part of the 20th century, few human caused impacts to these watersheds exist. The goal is based on measurable values not on value judgements.

4.3. References

Bauer, S.B., J. Golden and S. Pettit 1998. Lake Creek Agricultural Project, Summary of Baseline Water Quality Data. Pocketwater Incorporated, 8560 Atwater, Boise ID 83714. 138pp.

IDEQ, 1999a. North Fork Coeur d'Alene River Sub-basin Assessment. Idaho Department of Health and Welfare, Division of Environmental Quality, Coeur d'Alene Regional Office, 2110 Ironwood Parkway, Coeur d'Alene ID 83814. 44 pp.

IDEQ, 1999b. Coeur d'Alene Lake and River Sub-basin (17010303) Assessment. Idaho Department of Health and Welfare, Division of Environmental Quality, Coeur d'Alene Regional Office, 2110 Ironwood Parkway, Coeur d'Alene ID 83814. 37 pp.

MEMORANDUM

RECEIVED
NOV 30 1999
IDHW-DEQ
Coeur d'Alene Field Office

Date: 26 November 1999
To: Geoff Harvey, Coeur d' Alene R.O.
From: Nicholas Bugosh, Lewiston R.O.
RE: Peer Review of Subbasin Assessment

John Cardwell asked that I peer review the Coeur d' Alene Lake and River Subbasin Assessment. I went through the SBA, Wolf Lodge Creek, and Cougar and Mica Creek TMDL calculations and allocations. The review completed of those should help you revise the others. I marked comments in red as I read. Many are the sort of typos and small grammatical things that I know authors stop seeing after the n^{th} draft. Other comments marked on the draft are suggestions for improving readability. Use or ignore my suggestions as you choose and call if you want to discuss any of them.

Your concluding sentence on page 18, paragraph two has good wording. You might consider using that sentence as a template for similar summary sentences. As a global comment, I suggest using parallel sentence and paragraph construction when writing about the subbasin streams.

The following three comments are the really substantive issues that I have found with the paper.

1) The Idaho turbidity criterion is incorrectly described in the subbasin assessment. The instantaneous numeric value is 50 NTU <u>over background</u>. This generally means that during a suspected violation, the values are measured immediately downstream of the discharge where complete mixing has occurred and immediately upstream of the discharge. The point of the exercise is to show that the stream water quality changed as a result of the discharge.

Section 2.3.2.8. on page 20 states that, based on these data, the stream is water quality limited. Here the subbasin assessment says that anytime turbidity is greater than 50 NTUs we have a problem (regardless of whether that is a natural condition or not).

Erosion and sedimentation are normal, natural processes. Geomorphic evidence in our region suggest that these processes have been very active through the Quaternary. We know that presently the rain-on-snow and mid-to-late winter rain events produce episodic sediment pulses and we expect these to be associated with TSS far above 1.4 mg/L and turbidity far above 50 NTU. In essence, these water column data support the opposite argument, that the stream is not water quality limited by sediment. If the subbasin assessment has found that bedload is violating the sediment criterion, the data supporting that finding needs to be presented and discussed.

✓ wording on each ch.

2) RUSLE has been used here to model sedimentation of graveled roads. My understanding is that RUSLE was developed and validated on land disturbed by agriculture. Its use may be problematic here for roads because the roads are either hard-packed soil or gravel, instead of relatively loose, cohesionless soil. One problem with RUSLE that can lead to overestimation of sediment yield is that it has no provision for recognizing on-site sediment storage caused by change in slope, depressions, etc. You could incorporate this as a reason the estimate is

make clear new versions of RUSLE can be used in roads conservative, or try to estimate what proportion of RUSLE-modeled sediment would remain stored on the site. My quick calculations in the Cougar Kidd and Mica appendix, show the modeled rates would entirely remove the road bed in 124 years. This does not seem reasonable as we have logging, mining, and wagon roads that old that were not armored with gravel that are still around (without signs of eroding 8 inches deep).

3) The Margin of Safety discussion should be expanded. As written, it sounds as if the estimate was made less conservative, i.e., "subtracted from the estimated background." Because input parameters have been selected conservatively, and the model output is conservative because it does not include on-site storage, an additional margin of safety may not be needed, as per EPA (April 1991) guidance.

✓ language estimate conservative assumptions

Additionally, I offer some help with geologic nomenclature.

Geology means the science or study of the earth (earth science). Geologies is not a word. Thus, phrasing such as *Belt geologies* should be corrected throughout the document.

Lithology refers to the physical character of a rock and may be the word sought in some places when trying to discuss a rock fabric, but not a particular rock, e.g., 'This lithology weathers readily to sand.'

Terrane, the area over which a particular rock or group of rocks is prevalent, is the term most often needed. Do not confuse this term with *terrain*, which refers to "the lay of the land." The term is used when talking about *granitic terranes* or when comparing the erosivity of *the metasedimentary terrane (Precambrian Belt)* with another type.

incorporate

Note that *cobble* is not the opposite of the term *fine(s)*. Sediment particle sizes are as follows:

	mm
Clay	Smaller than 0.0039
Silt	0.0039-0.0625
Sand	0.0625-2.0
Gravel	2.0-64.0 (2.0 - <4.0 = granules, 4.0 - <64.0 = pebbles)
Cobble	64.0-256.0
Boulder	256.0 - 4096.0

defined fines as material smaller than clarification size

The term *fines* is often used to describe sizes from fine sand (0.125 to <0.25 mm) through clay. The textural term opposite of *fine* is *coarse*, as in 'The *fine* fraction (35%) is predominantly quartz sands while the *coarse* fraction (65%) consists of a mixture of mostly metamorphic boulders and cobbles, and gravels of igneous and metamorphic lithology'. I do not know how the term "stones" crept into the assessment for use as an opposite of *fines*, but it is not appropriate either.

Copy - [illegible]

United States Department of Agriculture	Natural Resources Conservation Service	Coeur d'Alene Field Office 1620B NW Blvd, Ste 101 Coeur d'Alene, ID 83814 (208) 667-2548

November 24, 1999

RECEIVED
NOV 30 1999
DEQ
CDA Regional Office

Goeff Harvey
Idaho DEQ
2110 Ironwood Parkway
Coeur d'Alene, Idaho 83814

Dear Mr. Harvey,

Thank you for the opportunity to review and comment on the draft TMDL for Wolf Lodge Creek. I forwarded the TMDL document to Rob Sampson, NRCS, one of our watershed engineering specialists in Boise and asked him to provide us with a detailed technical review. His comments are attached. I reviewed his comments and fully support his conclusions.

In addition to his comments, I have also included the bank erosion data you requested. Mark Hogen, Idaho Soil Conservation Commission, collected this data in the field in September 1999. Rob Sampson, NRCS, also field checked Mark's data and then completed the calculations for lateral recession and annual bank erosion. The data is summarized in tables labeled "Wolf Lodge Creek Lateral Recession Rate Estimate "(attached). Please let us know if you have any questions regarding this data. Please keep in mind that this data is field generated and specific to Wolf Lodge Creek and may not apply to other creeks in the Coeur d'Alene Basin or other North Idaho watersheds.

We appreciate the opportunity to be involved in the TMDL process especially where it relates to agricultural lands.

Sincerely,

David C. Brown
District Conservationist

Attachments

Cc; Rob Sampson, NRCS (w/o attachments)
Errol Arford, Kootenai-Shoshone SWCD
Tony Bennett, Idaho SCC

Comments on the draft Wolf Lodge Creek TMDL (no date shown)
R. W. Sampson, 11/17/99

General
The draft Total Maximum Daily Load (TMDL) allocation for sediment in Wolf Lodge Creek was reviewed. Wolf Lodge Creek is a 62.1 mi^2 tributary to Coeur d' Alene Lake in Kootenai County in northern Idaho. The catchment is steep (average slope of 40% estimated) with a base geology of belt metamorphics. The uplands are forestland used for timber production and constitute 95.6% of the catchment, while the bottomlands constitute 4.4 percent. All of the bottomland is privately owned and is divided evenly between the classifications of 'working ranch' and 'ranchette'. The forestland is 86% federally owned and 14% state and privately owned.

Authorities
Wolf Lodge Creek and its tributaries are listed as impaired by excess sedimentation in the 1998 303(d) list compiled by Idaho Division of Environmental Quality. Text of the TMDL indicates there has been a sub-basin assessment completed on Wolf Lodge Creek. There is no mention of analytic procedures or data collection methods that were employed in the assessment. ~ sediment model documented
sediment modeled not measured.

Loading (Section 3.1.3)
This section indicates that the excess sediment in Wolf Lodge Creek is interfering with the designated beneficial use, cold water biota. The same sentence describes this impairment as primarily coming from large bedload particles. Text indicates there has been no *quantitative* measurements of the impact of excess sediment. The text then lists four assumptions upon which the TMDL is developed given this lack of any data. The four premises, paraphrased, are:

1. At background levels of sediment movement and deposition, the stream is fully supportive of cold water biota.
2. The stream can assimilate and process sediment transport rates higher than background rates. Implicit in this statement is that an achievable steady-state condition exists, given a certain level of sediment input to the stream system.
3. Once this steady-state condition is reached, cold water biota will reach some 'level of full support'.
4. In order to link cold water biota populations directly to sediment, confounding factors such as fishing need to be accounted for.

using old TMDL

The background sediment rate for Wolf Lodge Creek is then listed as 15 tons/mile^2/year. A delivery ratio of 20% is assigned and the background loading rate of 183 tons/year for the catchment is determined. Later, this number is lowed to 165 tons/year to provide for a factor of safety.

Appropriate Measurement of Full Beneficial Use Support (Section 3.1.5)
The text reiterates that if rates of sediment delivered to the stream are reduced, then cold water biota will flourish. The yardstick for this level of sediment delivery is:

1. Three of more age classes of trout with one young of the year
2. Trout density reference levels of 0.1 to 0.3 fish / yard^2 / hour of effort.
3. Presence of sculpins and tailed frogs
4. Macroinvertebrate biotic index score of 3.5 or greater

The text then indicates that when these goals are obtained, the sediment loads will be revised. It is implied the sediment loads will be revised to whatever the (unmeasured) ← Should be stated. sediment levels are during the time when satisfactory measurements of the biotic indicators are made.

Sediment Load Allocation (Section 3.1.6)
Sediment is estimated to originate 75% (95.6% of the area) from the forest land use and 25% from the agricultural land use (4.4% of the area). Thus the 165 tons/year of sediment are proportioned between the land uses, and in the case of the forestland, further proportioned on the basis of area to the different landowners.

Similarly, the current sediment delivery amount of 1524 tons/year (25 tons/mile^2/year) (section 3.1.7.1) is assigned 75% to the forestland and 25% to the agricultural land. The difference between the current sediment delivery amount and the background sediment delivery amount is the reduction goal.

Agricultural Lands (section 3.1.7.3)
A separate section in the text is devoted to agricultural lands and concludes that the major sediment source around these lands is from stream bank erosion. This erosion is ascribed to riparian vegetation loss and channelization of the stream.

Monitoring Provisions (section 3.1.8)
Monitoring is stratified by Rosgen stream type and indicates that 5% of the channels will be measured every 5 years. Monitoring, the text states will measure the stream for 20 times the bankfull width along the channel. Measurements will be made to detect changes in the biotic indicators discussed in section 3.1.5. The text indicates that similar measurements will be made in 'reference reaches' in which target levels of cold water biota.

Feedback Provisions (section 3.1.9)
This section states that once the biotic indicator levels are met, no further sediment reduction activities will be required. It is reiterated that once these levels of full biotic support are met, the TMDL will be revised with whatever the ambient sediment levels are.

Comments

1. Aquatic ecosystems and their relationship to sediment as a stressor
Biotic indicators, particularly fish age classes and macroinvertebrate species distribution and density, have very high spatial and temporal variability. Coefficients of variability of 200 to 400% over time are common (Konditriav, 1992). Similarly, spatial variations are

common and large between habitat units and physical stream types (i.e., Dunham et. al, 1997). Because of this variability, statistical reliability of the monitoring plan indicated in sections 3.1.8 and 3.1.9 is in question. Measurement of items that have high variability requires high sample size, or sophisticated techniques to detect change with any certainty. To this end, process coefficients of variability should be estimated and published, and the sampling frequency calculated from these. Similarly, the sampling density in space is not clear, but seems lacking. The use of Rosgen stream types to stratify sampling is useless, particularly with the 'catch-all' category B (e. g., Miller and Ritter, 1995). There is no inherent predictability of stream behaviour among Rosgen-type stream classes (e. g., Meyers and Swanson, 1992; Sampson, 1996).

In addition, the direct linkage of the lack or abundance of sediment to the lack or abundance of fish or macroinvertebrates is absent in the literature. Quite the opposite, response to a stressor is seldom linear or singular (National Research Council, 1997; Peterson et. al., 1992; Wooten 1990).

Similarly, the use of reference reaches to determine salmonid densities is of questionable value. Salmonid abundance in Northwest mountain streams is primarily a function of physical stream attributes (Scrivener and Brownlee, 1989; Peterson et. al., 1992). Stream physical attributes in turn are a function of base landscape formative processes and past disturbance regimes. In other words, streams tend to be self-organizing entities around their own history (i.e., Stolum, 1996). Without calibration of population dynamics between two streams, particularly age and species distribution, no analysis can be made that a 'reference reach' will indicate how many fish should be present in another stream. The exception to this statement could be if some analysis of principle components or variance has shown the average population distribution that occurs in some physical stream type. This analysis would only be valid with an accompanying summary of errors used in the measurements and the analysis.

Given that biotic populations are hard to measure with certainty, that there is no one-to-one negative correlation of sediment with fish abundance or distribution, and that the use of reference reach information to select thresholds is questionable, the basic premise of the sediment TMDL as a direct link to fish populations seems weak. These poor assumptions could be buttressed to some extent by simply measuring grain-size distribution of the existing stream sediments, and intergravel dissolved oxygen levels as a percent of free water dissolved oxygen levels. These measurements could also be completed on 'reference reach' streams of similar slope and catchment size. Comparisons of this information would provide a more defensible basis for grouping streams or using the biotic attributes of one stream to predict what should occur in another.

2. Background erosion rates and sediment delivery amounts

The background sediment delivery amount of 15 tons/mile^2/year is unprecedented in the literature. Most other published values are one to almost two orders of magnitude higher than this rate (e.g., Langbein and Schumm, 1958, 360 tons/mile^2/year; Fournier, 1960, 580 tons/mile^2/year; Walling and Kleo, 1979, 300 tons/mile^2/year; Dunne, 1979, 120 to 300 tons/mile^2/year). All of the preceding references were calculated at an average annual precipitation of 28 to 32 inches per year. A table from multiple sources in Dunne and Leopold (1979), specifically for catchments smaller than 100 miles^2, shown no data indicating sediment yields below 50 tons per square mile, and very little below 100. The Kootenai River at Copeland averages 60 tons/mile^2/year (USGS) and this much larger basin undoubtedly has a lower unit delivery rate than a smaller one. Examining Table B-5 in Bunte and MacDonald (1999) does not indicate an average erosion rate under about 50 tons/mile^2/year for areas dominated by rain and rain-on-snow runoff processes.

Numbers similar to 15 tons/mile^2/year appear quite frequently as a base erosion rate in US Forest Service literature. This value was used as a base erosion rate in the WRENNS (USFS, 1980) document, and similarly transferred to the R1/R4 model (USFS, 1981). It originated from a rate of 25 tons/mile^2/year derived from a series of two studies by Walt Megahan and is then modified for basic geology and these were derived from a single publication. Reading the R1/R4 publication carefully, there are adequate warnings about how the data ranges well above 100 tons/mile^2/year, and that site-specific information should be used when possible. Although this warning is present, numbers between 10 and 25 tons/mile^2/year are often seen as base erosion rates in Forest Service documents, but values this small are seldom seen in other studies. Recently in a much more weathered landscape than north Idaho, measurements of *only* suspended sediment ran between 40 and 100 tons/mile^2/year (Scrivener and Brownlee, 1989). Including dissolved and bedload in this measurement would have increased it greatly. The landscape forming, long-term sediment delivery rate from Wolf Lodge Creek probably lies between 60 and 100 tons/mile^2/year, with an annual coefficient of variability of about 100% (e.g., Bunte and MacDonald, 1999).

coefficient for Long

60-100 Long

It would seem unreasonable to attempt to achieve a numerical standard of sediment delivery that was 3 to 6 times lower than landscape forming rate. Similarly, the estimated current sediment delivery rate of 24 tons/mile^2/year is not only well within (and below) the expected landscape forming sediment delivery rates, but given the process coefficient of variability of about 100%, it is indistinguishable from background rates on an annual basis.

did not see most current TMDL

3. Roads and road erosion

Literature of forest erosion rates is clear on one thing: roads are the largest and most detrimental sediment source in forested lands. Although many different erosion rates have been measured, most of the values converge around 2 pounds per square foot of active road surface per year (for a review see Sampson, Anderson and MacDonald, 1999). As scale increases, the apparent erosion rate decreases. Typically, an increase attributed to roads of about 0.4 pounds of sediment delivered per square foot of road is measured at the sub-basin scale. In this instance sub-basins are up to 3 square miles. Given the sediment allocation of 874 tons of sediment in the forest lands, and knowing roads are a primary source of sediment, back-calculations indicate 69 miles of eroding road surface on the forest. This is reasonable, given the catchment size.

Road erosion associated with real estate developments on the private ground could be a significant source of fine sediment.

did not see most recent TMDL or the assessment

4. Sediment sources from agricultural lands
Section 3.1.7.3 indicates that streambank erosion is the primary sediment source from agricultural lands, and suggests a reduction 340 tons per year from these lands. Given the indicated stream footage of 53,000 feet, and making the conservative assumption that half of the stream length is actively eroding, there is an apparent excess streambank erosion amount of 0.012 tons per foot of stream bank. Assuming a 2-foot average bank and an in-place density of 100 pounds per cubic foot, this is a lateral recession rate of over 0.13 feet per year. This is a very high rate, particularly for a temperate climate.

A stratified, random-designed sampling pattern measured lateral recession rates on almost 10% of the alluvial portion of Wolf Lodge Creek. Applying the rates to the five recognized stream segments indicated a sediment yield from bank erosion of approximately 30 tons per year along the alluvial section of Wolf Lodge Creek (coincidentally, the privately owned section). This measurement has an error of approximately +/- 40% (one standard deviation, log distributed) and has an annual process coefficient of variability of about 100%.

Sediment recession rate

5. Bedload as a pollutant
Although every form of erosion and subsequent sedimentation discussed in the TMDL text is for fine sediment, a single sentence in the text under section 3.1.3 indicates that *large bedload particles* are the primary interference with cold water biota. As stated, this is unsupported. Similarly, there is nothing in the literature that indicates bedload is a pollutant for aquatic ecosystems. Conversely, streams which have frequent gravel replacement are often favorite spawning areas (Wooten, 1989), and have typically high intergravel dissolved oxygen.

did not [illegible] PA

Streams adjust due to changes either in sediment input, water input, or boundary conditions. Although all of these disturbance mechanisms have a certain time frame for impact, most of the adjustment is complete in one to two, or possibly three disturbance cycles. For a stream that is most often a flood. Flooding has occurred in north Idaho in 1996 and 1997, 1980 and 1974. If the stream is in the process of assuming a new form due to a change, impacts may appear to be a result of direct streamside management, they often are a lagged response from upstream events.

Gravel moves fairly slowly through rough, mountainous streams (e.g., Bunte and MacDonald, 1999, page 297). Average travel distances of 350 feet per year (60 to 1000 feet) is suggested. This indicates that a disturbance such as a landslide occurring 6 miles above the agricultural ground may not cause a gravel-related impact in the valley for 90 years. There is undoubtedly attenuation in the disturbance magnitude, but the example shows how difficult it is to determine when the impacts of upstream disturbances will be realized.

A recent field visit to Wolf Lodge Creek, including several thousand feet of stream examined, did not show any signs of unprecedented bedload movement. Conversely, the

assessment in [illegible]

channel form and function seemed well within the norm with respect to particle sorting, bedforms, and local areas of deposition and scour.

Summary and Conclusions

Without measurements, numerical standards are impossible to achieve. If the standards are result oriented, there must be a minimum of confounding factors, or we might spend a lot of time and money trying to solve the wrong problem. Somehow, actual measurement, of suspended sediment at the least must be made. Locally used index procedures such as a Cumulative Watershed Effects Assessment (CWE, e.g., Washington Forest Practices Board, 1995) or the BURP procedure (IDEQ, Protocol 8, 1992) indicate where there may be problems, but they tend to lack resolution in determining actual physical process rates.

- Measurements of aquatic populations vary greatly from year to year and place to place. If aquatic populations are the yardstick by which success in pollution control will be judged, several things in this draft TMDL need to change.

  Sampling programs must be statistically defensible. Process variability and all relevant assumptions need to be well documented. Currently, this is not the case.

  If 'reference reaches' in another stream system are needed to bolster the data set, enough years of calibration need to be available to prove that populations respond similarly in the drainages under consideration. These data need to be made available, or the sampling strategy should not be accepted.

  A direct link between sediment movement and aquatic populations needs to be established. A surrogate, such as intergravel dissolved oxygen may be useful.

- Background, landscape forming sediment delivery rates need to be consistent with the accepted literature. The landscape-forming rate on Wolf Lodge Creek is most likely between 60 and 100 tons/mile^2/year.

- Similarly, erosion rates and sediment delivery volumes from roads need to be realistic. This does not appear to be a problem in the current load reduction recommended for Wolf Lodge Creek, although the reduction amount was derived from very low background erosion rates.

- Measurements indicate that streambank erosion on Wolf Lodge Creek is a minimal source of sediment. Local erosion around bridge abutments or gravel mining operations may be high, but erosion from normal fluvial processes is low. This low value is not unexpected given temperate climate, low channel slopes, and relatively unobtrusive land uses in Wolf Lodge Creek.

- The size of sediment that is of concern needs to be clarified. Similarly, if aquatic populations are being harmed by gravel transport, some reference to research or other findings is appropriate. If gravel introduced to the stream from the uplands is assumed to be a problem in the lowlands, the inherent travel time needs to be recognized. A field reconnaissance did not indicate any abnormalities in gravel transport rates.

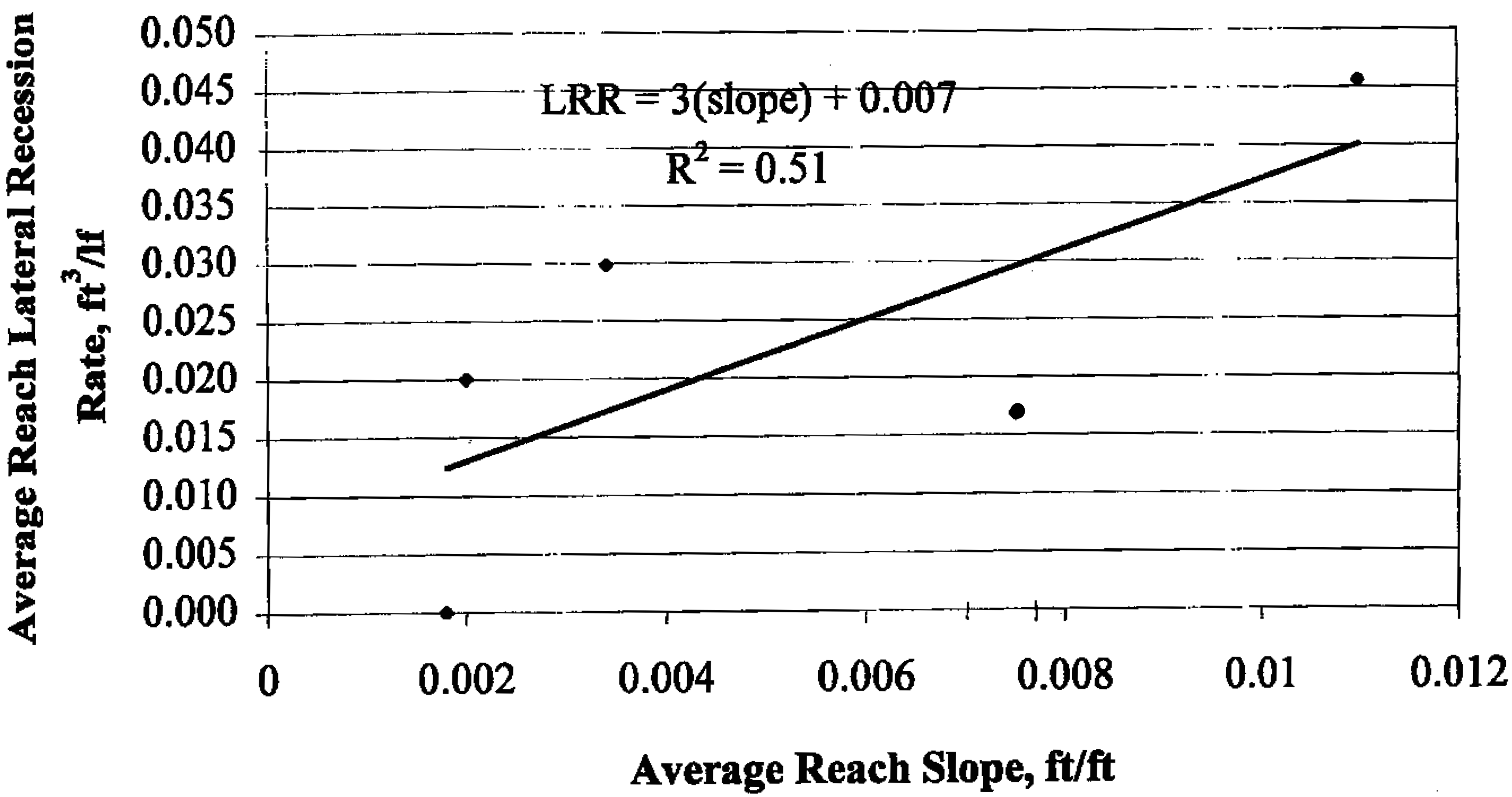
Wolf Lodge Creek
Lateral Recession Rate Estimate
Data Collected 9/16/99. Double checked 10/7/99
Assumed Sediment Density = 1.5 95 pounds/ft^3

Segment	Sample	Score	LRR ft/year	Average Bank Height feet	Length Examined feet	Eroding Length feet	Percent Eroding	Channel Forming Width feet	Bed Particle Size inches	Average Recession ft^3/lf	Reach Average ft^3/lf
1	None									0.000	0.000
2	1	3.5	0.04	2	500	125	25%	25	1	0.020	0.020
3	1	4	0.05	1.8	600	158	26%	30	2.5	0.024	
3	2	4	0.05	1.8	800	180	23%	40	1.5	0.020	
3	3	4	0.05	2.7	800	270	34%	43	2.5	0.046	0.030
4	1	4	0.05	2.5	500	241	48%	34	3.5	0.060	
4	2	3.5	0.04	2.3	600	202	34%	32	3.5	0.031	0.046
5	1	3	0.03	1.5	280	57	20%	14	5	0.009	
5	2	4.5	0.06	1.5	800	300	38%	40	3	0.034	
5	3	3	0.03	1.6	500	80	16%	25	3	0.008	0.017
				2.0	5380	1613	30%				

Segment	Length	Slope	LRR ft^3/lf	Erosion ft^3	Erosion pounds	Erosion tons
1	8400	0.0018	0.000	0	0	0
2	3600	0.002	0.020	72	6840	3
3	8800	0.0034	0.030	263	24944	12
4	4400	0.011	0.046	201	19066	10
5	9400	0.0075	0.017	159	15059	8
Total	34600					33

Wolf Lodge Creek

below confluence of Stella and Wolf Lodge Cr. to the mouth



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Kootenai Environmental Alliance
P.O. Box 1598 Coeur d'Alene, ID 83816-1598

Geoff Harvey
Idaho Department of Environmental Quality
2110 Ironwood Parkway
Coeur d'Alene, ID 83814

Dec. 14, 1999

Dear Mr. Harvey:

The following comments concern the DRAFT Coeur d'Alene Lake Sub-basin Assessment and TMDLs. There are also comments directed specifically for the Wolf Lodge Creek area and proposed TMDL.

A. The characterization of past logging on the Coeur d'Alene National Forest, page 5 under 2.1.2 Cultural Impacts, does not convey the actual amount of past logging on the Forest and should be rewritten in the DEQ Final Report.

The sentence states "Timber management has been moderately intense with large clear-cut areas and dense forest road development."
The Attachments with Forest Service data will show that the logging in the Forest should have been described as very intensive and concentrated to a large degree in a number of watersheds and drainages on the Forest. An analysis of the past logging will show that the logging did not take place uniformly over the entire Forest.

Attachment #1 indicates that Forest Service timber sales have clearcut over 56,000 acres on the Forest since 1965. This amounts to over 88 square miles of clearcuts.
Between the years 1980 and 1998, there has been over 28,000 acres, or over 44 square miles, clearcut on the Forest due to timber sales.
Additionally, there has been over 75,000 acres of regeneration logging that has taken place on the Forest since 1965. This amounts to over 117 square miles.

Attachment #2 lists the amount of regeneration and clearcut logging that has taken place in Compartments that include the Flat Creek, Yellowdog, Steamboat and Cougar Creek areas on the Coeur d'Alene NF.

An examination of the past Forest Service timber sales by Compartment will indicate the amount of acres logged in every Compartment on the Forest. A Compartment map for the Forest will

#2

show the Compartments that have had the most intensive logging, and the areas where the logging has been less intensive.

The DEQ Final Report should provide an analysis of the logging that has taken place in the Compartments that are part of and adjacent to, the Wolf Lodge Ck area. These are Compartments 367, 368, 369, 370, and 371. The analysis should include the figures for past regeneration and clearcut logging. The cumulative impacts, and direct and indirect effects to the watershed and drainages in the Wolf Lodge Ck area of the canopy openings from the logging should also be analyzed in the DEQ Final Report.

Also, in Appendix A of the Forest Service's Horizon Resource Area, Final EIS, Table A-1 lists the acres of past logging within the Wolf Lodge Creek Analysis Area, and Table A-1 is enclosed as Attachment #3.

The DEQ Final Report should also indicate that approximately 2,007 acres of logging associated with the Horizon Sun timber sale, including 443 acres of clearcuts, are within the Wolf Lodge Ck analysis area.

B. Page 9, Pollutant Sources
There is the following sentence "Excess sedimentation most often has its origins in roads developed for logging or access to a watershed and bank erosion associated with grazing."
We question as to why there is no mention of, and discussion of the release of sediment and larger material from hillslopes that has taken place and continues from past logging.
There is no mention on pages 9 or 10, of the findings in the Geomax Summary Report of Wolf Lodge Creek Stream Stability Analysis, June 21, 1988. The Summary Report was prepared for the Idaho Fish and Game by Dr. Donald Reichmuth and Mr. Dennis Findorff.

Pages 3 and 4 of the Geomax Report stated "The excessive sediment bedload carried by Marie Creek is not the result of natural sediment sources or in-stream recruitment of gravel resulting from developmental impact within the studied reach. Logging practices in the upper reaches of Marie Creek and its tributaries have left much of the upper watershed treeless. Figure 1 shows the relationship between forest cover and water yield and runoff. Precipitation falling on cleared mountain slopes causes immediate erosion during heavy rainfall and further erosion during spring snowmelt. This eroded material is carried into Marie Creek and substantially increases its volume of transported sediment."
Also, from page 4 "The shorter runoff period for precipitation falling on barren slopes can create flash flood conditions in streams fed by the runoff. Shorter runoff periods produce higher peak runoff volumes which are detrimental to stream channels. These high volume flows travel at relatively high velocity within the channel and, therefore, possess the kinetic energy which

causes excessive erosion. The effects of clear cutting practices on the bedload condition of streams is twofold: 1) The bedload is increased from eroded material from barren slopes carried by runoff, and 2) The bedload is increased from eroded bank and channel material caused by increased peak runoff volumes." The DEQ Final Report should include the statements and analysis contained in the Geomax Report.

There is also lengthy CSS/EPA analysis of the effects of logging related to forestry activities, including sediment production. I have enclosed these comments as Attachment #4. A few portions of the CSS/EPA analysis is contained in part F of our comments.

Page 11 discusses high temperatures in the River in relation to fish population. Despite the high temperatures, it is stated that trout and salmon are easily observed along the upper reach of the River. Is there data as to how many fish "were easily observed" in that section of the River? Was the fish count normal for that area, below average or above average? Also, have there been any concerns expressed by professional Fisheries Biologists regarding the high temperatures in the River? The DEQ Final Report should address these issues.

C. Page 20, Riffle Armor Stability
It is stated that "data of this type has not been collected for any of the water quality limited segments of the sub basin."

I have enclosed a copy of Forest Service RSI data that was included in the 1992 Fernan Ranger District Skookum EA, as Attachment #5. The RSI data concerns the Little North Fork of the Coeur d'Alene River and gives an indication of the bedload movement problems throughout the River System. The 4,000 acre Skookum Resource Area is just north of the Wolf Lodge Ck analysis area. The Skookum EA lists the RSI values, up to 96, for the watershed, pages 28 and 29 of Chapter III. The DEQ Final Report should analyze the RSI data for the Skookum Resource Area as it pertains to the Wolf Lodge Ck area.

In NF Assessment

D. Page 20, Residual Pool Volume
The Forest Service's Horizon Resource Area Final EIS has data in Chapter 2, pages 46, and 49 thru 57 regarding Wolf Lodge Creek, Marie Creek, and contains a discussion of suspended sediment production and sediment yield and water quality issues associated with the area. Chapter 3, pages 15 thru 20 have additional data regarding water quality and sediment yield.
The data in these Chapters should be analyzed in the DEQ Final Report regarding the discussion of Residual Pool Volume on pages 20 and 21 for Wolf Lodge Creek.

E. Page 22, Fish Population Data
I have enclosed a copy of pages 51, 52, and 53 with figures 1

thru 10 of a 1993 Forest Service Monitoring Project Summary that is found in the Panhandle Basin Status Report of 1994, section 7. This report is Attachment #6.

The report was written by the IPNF Forest Fisheries Program Manager. The data and findings in the Monitoring Summary should be included in and analyzed in the DEQ Final Report.

The findings on page 52 stated "Timber harvest and associated road construction appear to be the dominate land disturbing activities to which the observed shifts of habitat types and loss of pool volume and depth can be attributed. The results of these data suggest that watershed restoration activities may have to take priority over harvest activities in watersheds where channel stability is the over-riding consideration relative to restoring the physical and biological integrity of the aquatic ecosystem and that changes in harvest techniques and road density and location may be need(ed) to be incorporated into all future sales to maintain or improve channel stability and fish habitat."

F. Page 24, Forest land sediment yield and export
It is stated that the WATSED model was used to calculate the sediment yield. Page 28 also states that the WATSED model was used for Sedimentation Estimates.

Only WATSED coefficients used.

There are a number of significant flaws in the model that are not mentioned on either page or in Appendix B. The flaws are as follows.

(1): The model does not account for major storm events such as rain on snow events and does not calculate the sediment and larger material that is released from these events.

Our model did

(2): The model does not have the capability to calculate sediment or water yields for the hillslope length of individual logging units. This is critical due to the number of and size of clearcut units that are present on steep slopes in heavily logged watersheds on the Forest.

Our model did.

(3): The model does not account for the delivery of coarse material(larger than sand size) to stream channels and thus greatly under estimates the volume of material that may actually be delivered to stream channels, (Prichard Creek FEIS, Wallace Ranger District, April 1994, page 27 of Chapter III.)

Due to the flaws in the model, it is highly questionable as to whether the data given on page 25 and 29 is accurate. The DEQ Final Report needs to address the issue of how much material is actually being released from the hillslopes in the watersheds on the Forest that have been heavily logged and clearcut.

Appendix B also does not address the flaws of the WATSED model. There is no discussion or explanation in the Draft Report as to why there are so many damaged watersheds on the Forest in spite of the WATSED model being used. This model and the model that came before it, WATBAL, are supposed to be state of the art. WATBAL has been in existence for over 20 years and WATSED for over 10 years.

Regarding sediment routing and the WATBAL model, page 15 of the 1989 Technical User Guide states "It is recognized that this lack of accurate stream routing and insufficient recognition of stream dynamics is the weakest and as a critical element must be given top priority in future developments."

Concerning WATSED, KEA's copy of Version II of the document that describes the workings of the model is 109 pages long, excluding the Appendix. On page 11 of the document, under Routing and Storage it is stated "WATSED adapts Roehl (1962) channel sediment routing ratios." Since there is no discussion on page 11 as to how rain on snow events affect the channel sediment routing ratios, and it's inability to model hillslope lengths, it is questionable as to the accuracy of numbers given by the model in Appendix B as they relate to the National Forest lands.

Confused our use WATSED coefficient w/ use of WATSD

Also, on page 5 of Appendix B there are the following sentences "The model does not consider sediment routing. The model does not attempt to estimate the erosion to stream beds and banks resulting from localized sediment deposition in the stream bed." These two sentences directly contradict the statement on page 11 of the WATSED document concerning Routing and Storage.

Also, under Model Operation on page 5 of Appendix B, it is stated "The model is a simple Excel spreadsheet model composed of four spreadsheets." This implies that the WATSED model runs on a PC and does not involve many lines of code. KEA has information that the WATBAL model has 9,305 lines of code and the model runs on a IBM RS workstation and not on a PC.

The DEQ Final Document should indicate how many lines of code are in the WATSED model that runs on a PC and what are the hardware requirements to run the model on a PC. The date of the latest upgrades to the software, including the various datasets that are used in the model that runs on a PC also needs to be disclosed in the DEQ Final Report.

GIS data

In Appendix C are Sediment Model Data Spreadsheets.
The data supplied under Landuse, page 1, given for the Wolf Lodge Creek Sediment Budget, Wolf Lodge Watershed Use, does not agree with the data KEA has for these watersheds.
There is a figure given of a total of 147.3 acres of unstocked forest acres for Cedar Ck, Marie Ck, and Wolf Lodge Ck.
The Horizon Sun timber sale clearcut approximately 443 acres, these are unstocked acres and the sale is just now being completed.
Also, regarding the Marie Ck and Wolf Lodge Ck area, the Horizon FEIS Table A-1 that is mentioned earlier indicated that there

approximately 1,224 acres of past clearcuts from Forest Service timber sales. Since a majority of these clearcut acres have not recovered hydrologically, these acres should also be considered as being unstocked. The approximately 1,564 acres that have also been logged by the Horizon Sun timber sale contain a significant number of forest acres that are unstocked.
The wide disparity as to what is the true number of acres that are unstocked at this time in the Wolf Lodge Watershed needs to be addressed in the DEQ Final Document.
Data should also be supplied that will indicate the number of acres that have been clearcut in and adjacent to the Cedar Ck drainage from Forest Service timber sales.

Appendix C Sed Yield, page 1, Wolf Lodge Creek Sediment Yield and Export Budget from Land Use Types.
A figure of 4 tons is given for Unstocked Forests in the three watersheds. Due to the flaws in the WATSED model mentioned above, and the questions surrounding the true number of unstocked acres in these watersheds, the figure of 4 tons is not credible.

Appendix C Sed Total, page 1. Wolf Lodge Watershed Sediment Export.
The figure of 925.9 tons/yr for Land Use fines export also is not credible due to the flaws in the WATSED model and the questions regarding the actual number of unstocked acres in the three watersheds.

F. Page 32. Control Efforts to Date

We do not agree with the conclusion that pulling a few culverts and closing and/or removing some roads on the Forest will solve the water quality/water quantity/sediment/bedload problems in the Wolf Lodge Creek watershed.

The CSS/EPA document mentioned earlier has a extensive discussion of the factors that cause water quality, water quantity, sediment and peak flow problems in forests of the Northwest.
The document is titled Monitoring Guidelines to Evaluate Effects of Forestry Activities in the Pacific Northwest and Alaska, EPA/910-9-91-001, May 1991. Part II of the document is titled "Review of Monitoring Parameters".
I have excerpted a few of the discussions that are relevant to the issues of logging and sediment production, peak flows, and bedload problems. The Attachment #4 with Chapters 3, 4, and 5 of the CSS/EPA document contain a extended discussion of these issues with relevant comments highlighted.

From Chapter 3, Changes in Flow, on page 92 it is stated "Changes in the size of peak flows can have important implications for the stability of the stream channel, size and quantity of the bed material, and sediment transport rates."
On page 93 of Chapter III, it is also stated "Peak flows have

important effects on stream channel morphology and bed material particle size (Chapter 5). Specifically, since higher flows move larger particles, peak flows determine the stable particle size in the bed material (Grant, 1987). Large, stable particles provide important habitat niches for invertebrates and small fish. A highly unstable bed will reduce periphyton and invertebrate production (Hynes, 1970). The size of peak flows also is important in determining the stability of large woody debris and the rate of bank erosion." Also, "The vast majority of the sediment transport occurs during peak flows, as sediment transport capacity increases logarithmically with discharge (Ritter)."

Under a section titled Response to Management Activities on page 93, there are the following statements "Forest management activities can increase the size of peak flows by a variety of mechanisms, and these include the following: .... 3. reduced rain and snow interception due to removal of the forest canopy; 4. higher soil moisture levels due to the reduction of evapotranspiration; 5. increased rate of snowmelt; and 6. any change in the timing of flows that results in a synchronization of previously unsynchronized flows." And, "The effects of forest management activities on the size of peak flows have been studied in a number of paired watershed experiments in the Pacific Northwest and elsewhere(e.g., Harr, 1983; Bosch and Hewlett,, 1982). In most cases forest harvest has been found to increase the magnitude of peak flows, and this have been attributed to soil disturbance reducing infiltration and subsurface stormflow (Cheng et al. 1975), changes in short-term snow accumulation and melt (Harr and McCorison, 1979), and soil compaction (Harr et al., 1979)."

G. Page 33, Pollution Control Strategies

A planned system of pollution credits for more logging in watersheds on the Forest in conjunction with a Wolf Lodge Creek TMDL is unacceptable.

More logging with more canopy openings will not solve any of the problems associated with the increased peak flows and associated bedload movement in Wolf Lodge Creek and other watersheds on the Forest. As is pointed out in the Skookum EA, page 28 of Chapter III "Excess bedload movement is believed to be the major limiting factor in fish habitat on the Fernan Ranger District." And "The bedload fills pools, reducing both pool frequency and volume (Cross, pers. comm and memos)". The 1993 Callis Stewart EA, Fernan Ranger District, also stated on page 25 of Chapter III "Increased peak flows accompanying canopy removal have destabilized channels and dislodged sediment stored behind large woody debris."

The following information is taken from Sept. 1994 Coeur d'Alene River Cooperative River Basin Study, written by the USDA, the SCS, the Forest Service and the Kootenai-Shoshone Soil Conservation District.

On page 46 under Forest Erosion it is stated "It is difficult to identify which activity is most responsible for erosion and sedimentation problems at the basin level. Logging-related activities (forest canopy removal and roading) are likely a primary cause of erosion and sedimentation in the areas of the basin where these activities occur (primarily the Upper River). Logging related activities may also contribute to increased channel erosion and sedimentation in downstream areas due to hydrologic changes in the basin. It is easier to identify the causes at a smaller subbasin or tributary level. In tributaries such as Cougar, Steamboat, Yellowdog, Big Elk, and Teepee, it is easier to isolate logging as a primary cause of erosion and sedimentation." And "Logging-related activities past and present may be responsible for at least half the erosion and sedimentation problems in the Coeur d'Alene River Basin."

New logging with more canopy openings in the Forest will continue to add to the current bedload problem throughout the Forest. As is pointed out on pages 61 and 63 of the River Basin Study "Large openings created in the forest canopy allow greater snow accumulation, less interception and evaportranspiration, less infiltration, and ultimately more water available for runoff. When large openings are created throughout a drainage, the increased runoff equates to greater basin-wide water yield and stream energy. Much of this originates at upland sites near headwater stream reaches. In alluvial channels, the result is degradation of the nearby stream channels and deposition of the eroded material downstream. When such imbalances are maintained for many years, the long-term average condition is violated and the system resides in disequillibrium until a new long-term average condition is established along with a "new" equilibrium."

More logging with more canopy openings will not also address the problem of rain on snow events in the areas that have already been heavily logged, and which will not recover hydrologically for another 40 years or longer. The following statement is also from the Callis Stewart EA. Regarding the rain on snow model "The model does not allow for recovery of rain-on-snow until 40 years after harvest, at which point the stand is considered equivalent to a partial harvest until 68 years. The rain-on-snow recovery is premised on observations that existing clearcuts 40 years or older do not seem to be accumulating and retaining snow as much as do the younger clearcuts (H. Logsdon and S. Russell; Idaho Panhandle National Forests, pers. comm.; as well as information from technical literature, i.e. Harr and Coffin, 1991)."

The TMDL described on page 33 of the Draft that promotes pulling some culverts with road improvements and road obliterations does not address the full range of water related problems in the Wolf Lodge Ck area. These problems in the Wold Lodge Ck area and also on the Forest include hydrology and bedload movement problems, the continued destruction of important fisheries habitat, and

flooding in the Basin. These problems are completely ignored with a TMDL aimed exclusively at roads.
The Clean Water Act's (CWA) goal is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. An interim goal of the Act is the protection and propagation of fish, shellfish, and wildlife. The requirements of the CWA for protection and propagation of fish will not be met with a roads TMDL.

The DEQ Final Report also needs to state how the proposed road TMDL will meet the forthcoming EPA regulations regarding silvicultural activities as being considered point-sources of pollution.

H. Section 3.0 Draft TMDLs and 3.1 Draft Wolf Lodge Creek Watershed TMDL.
We do not agree with the first 3 premises on page 2 under Loading Capacity, due to the following Forest Service information.
The Forest Service's Horizon Final EIS, on page 22 of Chapter III stated "Fish populations and production are believed to have decline markedly over the past 10 to 15 years in north Idaho, including populations in Wolf Lodge Creek." Page 24 of Chapter III stated "Stream habitat conditions vary throughout the watershed, but tend to range from poor to fair with only occasional reaches of good or excellent habitat." Page 41 of Chapter IV also stated "Bedload production, deposition, and movement is believed to be a key factor in current and future fish habitat conditions." Page 44 also stated "The Wolf Lodge watershed is presently characterized as by large quantities of bedload moving through the drainage. Hence additional increases in bedload production or movement are viewed as generally negative impacts to the overall fish habitat conditions."

We also do not believe the figure given on page 2 of 910 tons per year for background sedimentation is accurate, due to the flaws in the WATSED model and the issue of unstocked lands in the 3 watersheds.

Page 3, Appropriate Measurements of Full Beneficial Support
The Forest Service's Douglas Fir Beetle Final EIS indicates that all the Creeks in the Wolf Lodge Ck area are presently functioning at risk, Chapter III pages 128, 129, 130, and 133. We do not believe the proposed roads TMDL will enable the any of the Creeks to attain a rating of full support for beneficial use. A roads TMDL ignores sediment loadings due to flows related to rain on snow events, and the continued bedload movement problems in the Wold Lodge Ck area.

Page 4 Sediment load reduction allocation
The reduction target of 710 tons per year allocated to the Forest Service is not credible. The water problems that already exist in the watershed from the current canopy openings have already been

mentioned and the reduction target completely overlooks these problems. There is also the related issue of two new timber sales being planned in the Wolf Lodge Ck area. Search for Horizon and Horizon Moon each are expected to log over 3 MMBF. Both sales will have more canopy openings, Search for Horizon alone will have over 40 more logging units. The proposed road TMDL with more logging continues with a business as usual approach to the water and fish problems in the Wolf Lodge Ck watershed.

Page 5, Monitoring and Feedback Provisions
The Forest Service has had a monitoring program and a feedback program for many years. The fisheries problems in the Wolf Lodge Ck area still exist and it is difficult to see how monitoring in-stream every five years will correct the current fisheries and bedload problems.

The CWA water quality standards that are required for the Wolf Lodge Creek watershed will not be met with the proposed road TMDL.
A new TMDL should be written that will fully and completely met all CWA water quality standards and requirements of the CWA.

Sincerely,
Mike Mihelich
Mike Mihelich

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United States Department of Agriculture

Forest Service

Idaho Panhandle National Forests

Coeur d'Alene River Ranger District

Silverton Office
P. O. Box 14
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Fernan Office
2502 East Sherman Avenue
Coeur d' Alene, ID 83814

File Code: 1950

Date: October 23, 1997

Mike Mihelich
Kootenai Environmental Alliance
P.O. Box 1598
Coeur d'Alene, ID 83816-1598

Dear Mr. Mihelich:

The following information is provided from the Timber Stand Activities database in response to your request dated September 6, 1997.

1. Approximately 701,166 acres of the Coeur d'Alene River Ranger District are classified as forested.

2. Approximately 74,911 acres have had regeneration harvests from 1965-1996 on the Coeur d'Alene River Ranger District. This includes clearcut, seedtree, selection, shelterwood, and liberation harvests.

3. Approximately 56,439 acres were clearcut harvested from 1965-1996 on the Coeur d'Alene River Ranger District. During the same period, salvage logging occurred on approximately 57,960 acres, and shelterwood harvests occurred on approximately 11,070 acres.

4. Approximately 14,889 acres were clearcut harvested from 1965-1969 on the Coeur d'Alene River Ranger District.

5. Approximately 13,049 acres were clearcut harvested from 1970-1979 on the Coeur d'Alene River Ranger District.

6. Approximately 17,287 acres were clearcut harvested from 1980-1989 on the Coeur d'Alene River Ranger District, with approximately 11,214 acres clearcut harvested from 1990-1996.

7. Between 1980 and 1989, clearcut harvest occurred on 969 acres in Compartment 138; on 1,276 acres in Compartment 139; on 356 acres in Compartment 140; on 131 acres in Compartment 141; on 820 acres in Compartment 142, on 469 acres in Compartment 143; on 180 acres in Compartment 144; on 1,580 acres in Compartment 145; and on 14 acres in Compartment 146. Between 1990 and 1996, clearcut harvest occurred on 128 acres in Compartment 138; on 72 acres in Compartment 139; on 127 acres in Compartment 140; on 0 acres in Compartment 141; on 435 acres in Compartment 142, on 0 acres in Compartment 143; on 479 acres in Compartment 144; on 10 acres in Compartment 145; and on 96 acres in Compartment 146.

8. Between 1980 and 1989, clearcut harvest occurred on 0 acres in Compartments 314, 319, 335 and 346; on 57 acres in Compartment 320; and on 285 acres in Compartment 357. Between 1990 and 1996, clearcut harvest occurred on 0 acres in Compartments 314, 319, 320, and 335; on 11 acres in Compartment 346; and on 192 acres in Compartment 357.

You also requested information regarding the amount of timber volume removed from the Coeur d'Alene Ranger District since 1965, and since 1980 in specific compartments. Our database records do not contain this information.

Susan Jeheber-Matthews

SUSAN JEHEBER-MATTHEWS
District Ranger

United States Department of Agriculture

Forest Service

Idaho Panhandle National Forests

Coeur d'Alene River Ranger District

Silverton Office
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File Code: 1950

Date: November 7, 1997

Mike Mihelich
Kootenai Environmental Alliance
P.O. Box 1598
Coeur d'Alene, ID 83816-1598

Dear Mr. Mihelich:

The following information is provided from the Timber Stand Activities database in response to your request dated November 1, 1997.

Compartment #	Acres	Acres of Regeneration	Acres of Clearcut Harvests
138	9,992	3,119	2,672
139	11,471	4,871	4,348
140	4,757	815	815
141	4,635	131	131
142	8,637	2,968	2,514
143	7,640	4,115	2,187
144	5,867	933	898
145	8,662	3,439	2,146
146	4,062	242	137
181	5,921	585	378

Please note that under some regeneration methods, a second treatment may occur on the same acres. For example, a shelterwood is a regeneration harvest method in which some of the trees remain following initial harvest to supply seed and shelter for the remaining stand. Final removal of the shelterwood trees may or may not occur following regeneration establishment (5 to 15 years).

If you have additional questions, please feel free to contact either Steve Bateman or me at 769-3000.

Susan Jeheber-Matthews

SUSAN JEHEBER-MATTHEWS
District Ranger

E3

ATTACHMENT #3

Table A-1. Past Harvest Openings and Recovery Status by Resource.

STAND ID	ACRES	YEAR OF HARVEST	TREATMENT	TREE DENSITY (TPA)¹	HEIGHT RANGE (FEET)	AVERAGE HEIGHT (FEET)	TIMBER RECOVERY	WATERSHED RECOVERY	WILDLIFE RECOV-ERY	VISUAL RECOVERY
67-202	11	1977	Clearcut	2500	7-10	8	Yes	.4	Yes	No
67-204	11	1977	Clearcut	2900	3-12	7	Yes	.5	Yes	No
67-205	41	1977	Clearcut	1400	7-9	6	Yes	.3		No
67-303	5	1977	Permanent	<25	<1'	1'	No	.1	No	No
67-601	37	1971	Clearcut	650	6'-12	7	Yes	.2	Yes	No
67-602	70	1972	Clearcut	1900	5-12	7	Yes	.4	Yes	No
67-701	52	1974	Clearcut	300	5-14	5	Yes	.2	No	No
67-702	50	1974	Clearcut	1250	11-14	12	Yes	.4	Yes	No
67-705	9	--	Clearcut	100	4-6	5	Yes	.1	No	No
68-101	57	1974	Clearcut	2700	6-18	10	Yes	.7	No	No
68-102	34	1974	Clearcut	1050	6-17	11	Yes	.6	Yes	No
68-103	8	1974	Shelterwood	1500	4-15	9	Yes	.5	Yes	Yes
68-104	38	1974	Clearcut	200	1-20	5	Yes	.2	No	No
68-105	9	1974	Clearcut	600	4-7	5	Yes	.2	No	No
68-106	9	1974	Clearcut	1100	5-20	8	Yes	.5	Yes	No
68-401	6	1966	Clearcut	5500	5-18	10	Yes	.6	Yes	Yes
68-402	9	1966	Clearcut	300	5-10	8	Yes	.4	Yes	Yes
68-526	3	1966	Clearcut	300	5-10	8	Yes	.4	Yes	Yes
69-105	15	1970	Clearcut	300	3-10	6	Yes	.4	No	No
69-111	13	1989	Clearcut	450	<1	<1	No	.1	No	No
69-241	6	1970	Clearcut	300	3-10	6	Yes	.4	No	No
69-302	90	1972	Clearcut	1250	5-18	11	Yes	.8	Yes	No
69-305	45	1974	Shelterwood	800	2-11	7	Yes	.8	Yes	No
71-104	41	1987	Clearcut	450	<2	1	No	.1	No	No
71-301	30	1974	Clearcut	1000	2-5	3	Yes	.2	No	No
71-401	113	1969	Clearcut	300	4-10	8	Yes	.2	Yes	No
71-402	4	1969	Clearcut	400	2-9	5	Yes	.3	No	No
71-404	92	1972	Clearcut	800	6-7	6	Yes	.3	No	No
71-406	8	1974	Clearcut	600	3-12	8	Yes	.5	Yes	No
71-408	3	1969	Clearcut	400	5-18	9	Yes	.7	Yes	No
71-501	160	1969	Clearcut	450	6-18	10	Yes	.8	Yes	No
71-601	186	1968	Clearcut	450	10-20	15	Yes	.8	Yes	No
71-619	5	1968	Clearcut	450	15-30	20	Yes	.8	Yes	No
	1277		OTHER TREATMENTS OF CONCERN							
69-301	127	1974	Liberation	550	3-15	8	Yes	.8	Yes	No
69-306	12	1974	Liberation	1000	3-12	6	Yes	[illegible]	[illegible]	

EPA

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Alaska
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Water Division

May 1991

EPA/910/9-91-001

CSS

Center for Streamside Studies, AR-10
College of Forestry and College of Ocean and Fishery Sciences

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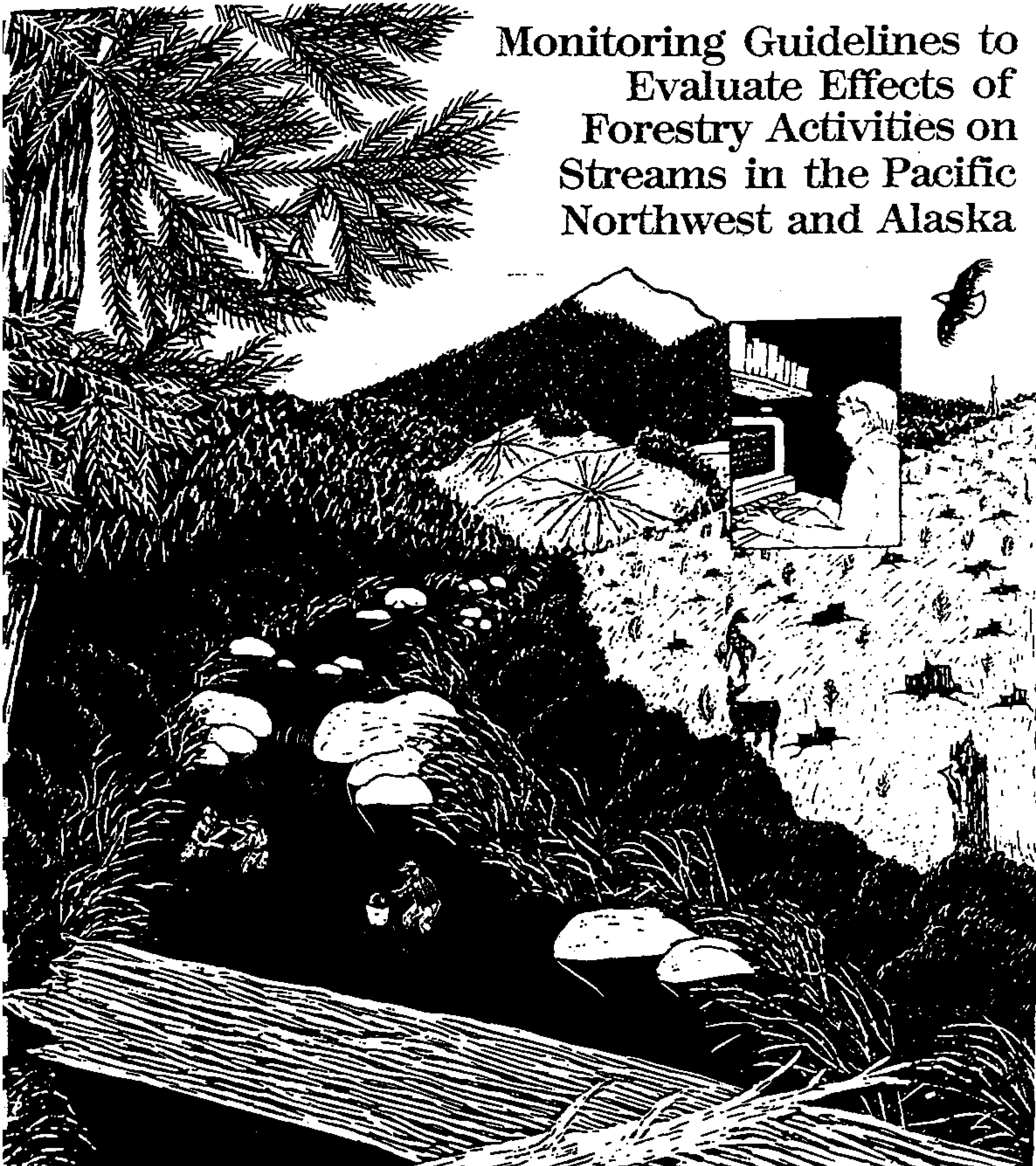
Seattle, WA 98195

Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska



EPA 910/9-91-001

MONITORING GUIDELINES TO EVALUATE EFFECTS OF FORESTRY ACTIVITIES ON STREAMS IN THE PACIFIC NORTHWEST AND ALASKA

LEE H. MACDONALD

WITH

ALAN W. SMART AND ROBERT C. WISSMAR

These Guidelines were developed for Region 10, U.S. Environmental Protection Agency,
Seattle, Washington, under EPA Assistance No. CX-816031-01-0
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College of Forest Resources/College of Ocean and Fishery Sciences
University of Washington
Seattle, Washington

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Page

PART II. REVIEW OF MONITORING PARAMETERS

3. CHANGES IN FLOW

INTRODUCTION

Changes in the size of peak flows, the discharge at low flows, or annual water yield usually are not considered as water quality parameters. Nevertheless, forest harvest, road building, and other management activities can result in substantial changes in the volume and timing of runoff, and this has long been a source of public concern. Changes in the size of peak flows can have important implications for the stability of the stream channel, size and quantity of the bed material, and sediment transport rates. An increase in low flows generally will reduce peak summer temperatures and increase the available fish habitat. Changes in water yield typically are too small to be measured, but in high elevation basins with extensive hydropower development the theoretical increase in water yield can have substantial economic value. In some areas the evaluation of cumulative effects is based largely on the estimated capability of the stream channel to accommodate an increase in discharge.

Flow parameters were included in the *Guidelines* because of their potential sensitivity to forest management activities, their relationship to designated uses, and general public concern. Even if a flow parameter is not explicitly included in a monitoring project, discharge measurements are needed to interpret other data, such as turbidity and conductivity, and to calculate the total flux of nutrients, sediment, and other materials being transported by streams.

In summary, the patterns and values of discharge are important characteristics of forest streams, and they integrate all the different effects of specific management activities on the hydrologic cycle. Maintaining favorable conditions of flow was an important justification for establishing the National Forest system, and this concern persists to the present day. Forest management activities can affect discharge through a variety of individual processes, and this chapter reviews the three parameters of greatest concern.

3.1 INCREASES IN THE SIZE OF PEAK FLOWS

Definition

Peak flows refer to the instantaneous maximum discharge associated with individual storm or snowmelt events. The diversity of climates in EPA's Region 10 means that peak flows can result from several different types of climatic events. In the low-lying, coastal basins in the Pacific Northwest, for example, winter rainfall is the primary cause of peak flows. In many of the higher-elevation and interior areas, peak flows are generated by spring snowmelt. Other possible causes of peak flow events are summer thundershowers and rain-on-snow events. Both of these latter causes may be less common and less predictable, but in certain basins they may be responsible for the largest runoff events.

Many basins may be exposed to more than one cause of peak flows. For example, spring snowmelt may generate the peak discharge in most years for a given basin, but less common rain-on-snow events may be responsible for the largest discharge events. Prediction of the effects of forest management on the size of peak flows is complicated by the fact that forest management will have quite different effects on the size of peak flows depending upon whether the peak flows are caused by spring snowmelt, high-intensity rain storms, or rain-on-snow events. The effect of forest harvest and other management activities also will vary according to factors such as the type of yarding (tractor or cable), the density of skid trails and landings, soil type, and soil moisture content. Prediction of the effect of management on the size of peak flows therefore requires (1) knowledge of the climatological events that cause the peak flows in the basin of interest, (2) specification of the peak flows of concern (e.g., the mean annual flood or more extreme events such as the 50-year flood), and (3) specific knowledge on how the management activities are likely to affect each of the major components of the hydrologic cycle (interception, infiltration, evapotranspiration, and snowmelt).

Relation to Designated Uses

Peak flows have important effects on stream channel morphology and bed material particle size (Chapter 5). Specifically, since higher flows move larger particles, peak flows determine the stable particle size in the bed material (Grant, 1987). Large, stable particles provide important habitat niches for invertebrates and small fish. A highly unstable bed will reduce periphyton and invertebrate production (Hynes, 1970). The size of peak flows also is important in determining the stability of large woody debris and the rate of bank erosion. Increased bank erosion and channel migration will affect the riparian vegetation and alter the amount of active sediment in the stream channel. Periods of high flow also are periods of bank building and deposition on active floodplains, especially in areas with dense riparian vegetation.

The vast majority of the sediment transport occurs during peak flows, as sediment transport capacity increases logarithmically with discharge (Ritter, 1978; Garde and Ranga Raju, 1985). The ability of the stream to transport the incoming sediment will help determine whether there is deposition or erosion within the active stream channel. The relationship between sediment load and sediment transport capacity will affect the distribution of habitat types, channel morphology, and bed material particle size (Chapter 5). Increased size of peak flows due to urbanization have been shown to cause rapid channel incision and severe decline in fish habitat quality (Booth, 1990).

A change in the size of peak flows can have important consequences for human life and property. Structures such as bridges, dams, and levees are designed according to a presumed distribution of peak flows. If the size of peak flows is increased, this could reduce the factor of safety and lead to more frequent and severe damage.

Response to Management Activities

Forest management activities can increase the size of peak flows by a variety of mechanisms, and these include the following:

1. road-building (due to both the impervious surface and the interruption of subsurface lateral flow);
2. reduction of infiltration rates and soil moisture storage capacity by compaction;
3. reduced rain and snow interception due to removal of the forest canopy;
4. higher soil moisture levels due to the reduction of evapotranspiration;
5. increased rate of snowmelt; and
6. any change in the timing of flows that results in a synchronization of previously unsynchronized flows.

By the same logic indicated in item 6 above, forest harvest may reduce the size of peak flows by desynchronizing runoff peaks (Harr, 1989). Under certain conditions forest harvest also can reduce the size of the smaller peak flows by reducing fog drip, thereby reducing the amount of soil moisture storage prior to some storm events.

Each of these mechanisms will have different effects in different seasons and in storms of different magnitudes. Sufficient care in the layout and execution of roads and timber harvest will minimize the changes in the size of peak flows from the first four runoff processes identified above. Thus in the absence of rain-on-snow events, the most dramatic changes in the size of peak flows are observed in the smaller storms in autumn or early winter, when less precipitation is needed to recharge soil moisture (e.g., Harr et al., 1975; Ziemer, 1981). Forest management activities can have a relatively negligible effect on the peak flows associated with major floods if very little of the catchment has been subjected to compaction or converted to an impervious surface.

The effects of forest management on peak flow size are quite different when the largest floods are caused by rain-on-snow events. In these areas, forest management—by increasing snowpack accumulations in openings and increasing the rate of snowmelt in clearcuts and young plantations (Berris and Harr, 1987)—can increase the size of peak flows in major flood events.

The effects of forest management activities on the size of peak flows have been studied in a number of paired watershed experiments in the Pacific Northwest and elsewhere (e.g., Harr, 1983; Bosch and Hewlett, 1982). In most cases forest harvest has been found to increase the magnitude of peak flows, and this has been attributed to soil disturbance reducing infiltration and subsurface stormflow (Cheng et al., 1975), changes in short-term snow accumulation and melt (Harr and McCorison, 1979), and soil compaction (Harr et al., 1979).

A few studies have shown no significant changes in the frequency or magnitude of peak flows (Harr, 1980; Harr et al., 1982; Wright et al., 1990). In one case the absence of an increase in the size of peak flows was due at least in part to a reduction in fog drip; one must also assume there was minimal soil compaction and soil disturbance. The lesson from these studies is that forest management can have a variety of interacting hydrologic effects, and the sum of these effects will determine whether an increase in the size of peak flows is likely (Harr et al., 1982).

Measurement Concepts

Peak flows can be identified either by continuous measurement of stage (water surface elevation) or by the use of crest stage recorders. Usually stage is converted to discharge by periodically surveying the stream cross-section and measuring stream velocity at various water surface elevations. The calculated discharge is then plotted against stage to obtain a rating curve (Buchanan and Somers, 1969).

The conversion of stage to discharge is needed in order to establish a quantitative relationship between peak flows in two or more basins. Changes in the size of peak flows can then be detected by a change in this relationship. Direct comparisons of stage heights between basins is not appropriate because the relationship between stage and discharge is unique for each location and may change over time as the channel erodes, aggrades, or shifts laterally.

The comparison of discharge from similar, adjacent catchments is the most sensitive means to detect changes in the size of peak flows. Usually at least 3 years of calibration data are needed to establish a relationship capable of predicting about 70-85% of the variance in discharge. A proportionally longer calibration period will be needed to establish a valid statistical relationship for peak flows with longer recurrence intervals. The pre-disturbance discharge relationship is then used to determine if there is a statistically significant change in discharge due to management activities in one of the catchments.

An alternative to the paired-catchment approach is to relate the stage or discharge at one location to precipitation, and then assess how this rainfall-runoff relationship changes with management. The difficulty with this technique is that rainfall-runoff models are relatively crude, and the uncertainty associated with rainfall-runoff model predictions generally increases with increasing discharge. This uncertainty then makes it very difficult to identify a change in the size of peak flows due to management activities.

Direct measurement of peak flows can be obtained by continuous measurements of water level or by crest-stage recorders. Continuous measurement of discharge usually requires constructing a stilling well and establishing a stage-discharge relationship. This is relatively expensive and requires a continuing input of staff time to check on the stage recorder, establish a stage-discharge relationship, and transform the stage data to discharge.

Crest-stage recorders are much simpler, as they only record the maximum water level. In the absence of a stage-discharge relationship, the values may be difficult to interpret, as changes in channel morphology can alter the observed crest from events with identical peak discharges. Typical crest stage recorders consist of vertical tubes containing powdered cork. Small holes in the tube allow water to enter and leave the crest gages, and a ring of powdered cork is left at the highest water level occurring between observations.

A major problem in monitoring changes in the size of peak flows is the infrequent nature of high flow events. Hence sample sizes are small, and the capability to detect a statistically significant change is low. For this reason most research addressing changes in peak flows have focused on runoff events that occur several times each year. Monitoring changes in the size of peak flows associated with storms with longer recurrence intervals is much more difficult. A 5-year storm, for example, only has a 20% chance of occurring in a given year, and only a 67% chance of occurring within a specified 5-year period. Hence a very long calibration period is needed for these rarer events, and the post-harvest monitoring period is limited by the hydrologic recovery of the site to pre-harvest conditions. For this reason changes in the size of the larger peak flows generally cannot be measured directly.

Monitoring changes in the size of peak flows is also limited by the cost of establishing and maintaining stations to measure peak discharges. Continuously recording gaging stations are relatively costly. Discharge measurements during high flow events require some access to the site and a structure from which one can safely measure velocity. Crest-stage recorders are relatively simple and inexpensive, but they have a much lower sensitivity.

Standards

No standards for changes in the size of peak flows have been established or proposed.

Current Uses

The difficulties in determining a change in the size of peak flows means that this parameter is rarely included in most monitoring projects. Nevertheless, potential changes in the size of peak flows can be an important constraint to forest management (Grant, 1987), particularly in areas subject to rain-on-snow events. Hence most environmental assessments and other planning documents evaluate projected changes in the size of peak flows by extrapolating from the limited number of paired-catchment experiments that have examined the issue.

It is important to note that any change in the size of peak flows is most likely to decline in magnitude as one moves downstream. This is due to both a dispersion of the flood wave in time and the lack of change in other tributaries (i.e., a dilution effect) (Linsley et al., 1982). Proportionally larger increases in the size of peak flows will occur downstream only if the timing of peak runoff in the managed basin is altered in such a way that it becomes synchronized with peak runoff in other tributaries (Harr, 1989).

Assessment

Forest management activities can increase the size of peak flows by transforming subsurface flow to surface flow, reducing infiltration rates and soil moisture storage capacity, reducing interception losses, increasing soil moisture, and altering rates of snowmelt. The relative effects of these changes will vary by season, site, and storm size. Careful management and post-harvest rehabilitation measures can largely alleviate changes in the size of peak flows due to compaction, disruption of subsurface flow paths, and reduced infiltration rates. This means that in areas not subject to rain-on-snow events, the largest change in the size of peak flows can be limited to the first few storms following the growing season, when the higher soil moisture carryover results in a greater proportion of runoff. Major floods, such as those with a return interval of 50 years or more, should not be as greatly affected by forest management activities, as the total rainfall is normally sufficient to make up any initial differences in soil moisture content. However, if forest harvest and other management activities substantially increase the amount of compacted or impervious areas (e.g., roads, landings, and skid trails), the size of peak flows from all storms is likely to increase (Harr et al., 1979).

Forest harvest can increase the size of the largest peak flows in areas where the largest floods are caused by rain-on-snow events. This increase in the size of peak flows is due to the combination of increased snowpack (caused by a reduction in interception losses) and an increase in snowmelt due to increased turbulent heat transfer. Recent research in the Washington Cascades has indicated that harvested plots can yield up to 95% more runoff than unharvested areas, and runoff from 18- to 20-year-old plantations is around 40% higher (R.D. Harr, U.S.F.S. Pac. Northw. Res. Sta., Seattle, pers. comm.).

In summary, the effects of forest harvest on the size of peak flows is difficult to predict and measure. Providing that soil disturbance and compaction are kept to a minimum, concern over increases in the size of peak flows is appropriate primarily in areas where rain-on-snow events generate the largest flood peaks. Careful monitoring of changes in the size of peak flows could help provide some insight into the hydrologic behavior of a basin, but there are more direct and efficient ways to monitor most of the physical effects that lead to a change in peak flows.

Monitoring of changes in the size of peak flows is difficult because it requires a long-term commitment and the matching of the basin of interest to one with no land use changes or management activities. Data from past studies on small catchments indicate that monitoring the size of peak flows provides little understanding unless it is accompanied by studies documenting the probable cause(s) of any observed change. Hence, monitoring the size of peak flows is more appropriate as part of an applied research project than as a standard monitoring practice.

3.2 CHANGES IN LOW FLOWS

Definition

In most of the western U.S., the minimum streamflow is observed during the late summer and early autumn. This decline in discharge is due to a combination of low precipitation, reduced drainage from the soil and bedrock, and sustained high evapotranspiration. Removal of the forest or other vegetative cover usually results in an increase in low flows by reducing evapotranspiration (e.g., Harr et al., 1979) and secondarily, interception.

Relation to Designated Uses

Summer low flows are important primarily for maintaining aquatic habitat. An increase in low flows will increase the wetted perimeter and flow depth, and thereby provide more habitat. Increased flows will also reduce the magnitude of any temperature increase due to forest harvest, as temperature increases are highly dependent on the increase in incoming net radiation relative to total discharge (Section 2.1).

Response to Management Activities

In most small catchment studies in the Pacific Northwest forest harvest has been shown to increase summer low flows by up to 300% (Anderson, 1963; Rothacher, 1970). Although this is a large relative increase, the absolute volume of the increase is small relative to the total annual water yield (Harr et al., 1982). However, in areas where fog drip is a major hydrologic input, forest harvest can cause a decline in summer low flows (e.g., Harr, 1980). Studies in the drier, snowmelt-dominated areas of the Rocky Mountains have shown low flow increases of only 0-12% following forest harvest (Bates and Henry, 1928; Troendle, 1983; Van Haveren, 1988). The presence of a low flow increase in these more arid environments may depend on whether summer precipitation is sufficient to generate a response in streamflow.

As forest regrowth occurs the increase in low flows is diminished, and the rate at which low flows return to pre-harvest conditions can be highly variable. In coastal Oregon the harvest of a mature coniferous forest was followed by the rapid establishment of phreatophytic vegetation (red alder, cottonwoods, and willows) in and adjacent to the stream channel. Within 10 years the measured summer low flows showed no increase relative to pre-harvest conditions, and in subsequent years the summer low flows were less than predicted by the pre-harvest calibration equation. This reduction in low flows can be expected to continue until the phreatophytic vegetation is overtopped by the less water-consumptive coniferous species (Harr, 1983). Hydrologic recovery from thinning, understory removal, or burning of brush also is likely to require less than a decade.

Measurement Concepts

As was the case for peak flows, the most sensitive means for detecting a change in low flows is to establish a statistical relationship between the discharge of adjacent catchments. A change in the relationship between the two catchments is used to demonstrate a change in low flows. The need to accurately measure relatively small discharges means the gaging stations must be carefully placed to minimize seepage, and the width-depth ratio should be as low as possible. In small streams some type of weir or flume structure is likely to be needed to obtain the necessary accuracy.

Changes in low flows generally will be more difficult to detect in larger catchments because a smaller proportion of the catchment will be harvested over a relatively short time period. Hence any increase in low flows will be subject to a dilution effect from other sub-catchments which do not have a hydrologically altered vegetation canopy.

Standards

No standards for changes in low flows have been established or proposed.

Current Uses

Monitoring stream discharge is an important component of most water quality monitoring programs. However, low flows are relatively unimportant in terms of their contribution to constituent load, sediment load, and water yield. Paired-catchment experiments have shown that 20-30% of a catchment must be cleared to obtain a measurable increase in water yield (Bosch and Hewlett, 1982). Since most long-term gaging stations are on larger catchments that do not experience such heavy harvest levels over a relatively short time period, changes in low flows are unlikely to be observed at existing gaging stations.

Little attention has been paid to monitoring changes in low flows because there is very little scope for management. Removal of the riparian vegetation usually is not a viable option because of concerns over wildlife and fisheries habitats, sediment and nutrient inputs, bank erosion, and stream temperatures (Section 6.2). Forest harvest is known to decrease evapotranspiration, and some of this water will be expressed as an increase in streamflow, but we have very limited control over the amount and timing of this increase. Although this increase in low flows may be significant in terms of increased habitat area—particularly in small streams—on larger streams the increase generally is too small to be measured. For these reasons most monitoring projects do not explicitly attempt to document any change in low flows.

Assessment

Forest harvest can cause a substantial increase in summer low flows, and this will provide additional habitat for stream biota. Increased low flows also may reduce the susceptibility of the stream to adverse temperature changes resulting from removal of the riparian canopy. Thus changes in low flows may be beneficial and of interest to managers, but low flows generally cannot be used as an indicator of water quality. To date, water rights courts have not addressed the allocation of any increase in water yield due to forest harvest. The absence of any institutional mechanism to capture the economic benefits of increased low flows, and the difficulty of measuring small increases on large basins, indicates that low flow monitoring is rarely appropriate.

3.3 Water Yield

Definition

A change in water yield represents the sum of all the individual changes in runoff over a water year. Most paired-watershed experiments have focused on changes in the total annual water yield, so there is much more data on changes in water yield than on changes in low flows or the size of peak flows.

Relation to Designated Uses

The importance of an increase in water yield depends on the timing of the increase, the uses of the water, and the extent to which the increase can be captured by storage facilities. In rain-dominated or warm snow environments, the largest relative increases in water yield usually occur during the summer and first autumn storms (Harr, 1983). The largest absolute increases occur during the fall-winter rainy season (Harr et al., 1982).

In colder, snow-dominated environments most of the increase in water yield will occur early in the spring snowmelt period because less snowmelt is needed to recharge soil moisture (e.g., Troendle and King, 1985). If there is sufficient precipitation during the summer and fall to generate substantial amounts of streamflow and maintain high levels of soil moisture, water yield increases also may be detected in these periods (e.g., Swanson and Hillman, 1977).

The significance of an increase in low flows was discussed in Section 3.2; the likelihood and significance of increasing peak flows was discussed in Section 3.1. Other than the possible increase in the size of the larger peak flows due to rain-on-snow events, the increase in fall and winter discharge from forest activities is likely to have little biological or physical significance. However, any increase in flow may be beneficial if it can be captured in a downstream reservoir and used for generating electricity, irrigation, or water supply purposes.

4. SEDIMENT

Introduction

An increased sediment load is often the most important adverse effect of forest management activities on streams. Large increases in the amount of sediment delivered to the stream channel can greatly impair, or even eliminate, fish and aquatic invertebrate habitat, and alter the structure and width of the streambanks and adjacent riparian zone.

The physical effects of increased sediment load can be equally far-reaching. Fine sediment can impair the use of water for municipal or agricultural purposes. The amount of sediment can affect channel shape, sinuosity, and the relative balance between pools and riffles. Changes in the sediment load also will affect the bed material size, and this in turn can alter both the quantity and the quality of the habitat for fish and benthic invertebrates.

Many nutrients and other chemical constituents are sorbed onto fine particles, so sediment loads are often directly related to the load of these constituents. Indirect effects of increased sediment loads may include increased stream temperatures and decreased intergravel dissolved oxygen (DO).

These wide-ranging effects suggest that there are an equally broad range of techniques that can be used to assess the quantity and impact of the sediment load in a particular stream. Direct measurements include suspended sediment concentration, turbidity, and bedload. Indirect methods include measurements of channel characteristics such as the width-depth ratio, residual pool depth, bed material particle size, or the width of the riparian canopy opening (Sections, 5.2, 5.3, 5.6, and 6.1, respectively). This chapter discusses only the parameters of suspended sediment, turbidity, and bedload.

4.1 Suspended Sediment

Definition

Suspended sediment refers to that portion of the sediment load suspended in the water column. This, at least conceptually, is distinct from bedload, which is defined as material rolling along the bed. The relative size of particles transported as bedload and suspended sediment will vary with the flow characteristics (e.g., velocity, bed forms, turbulence, gradient) and the characteristics of the material being transported (e.g., density, shape). For the Pacific Northwest and Alaska, particles <0.1 mm in diameter (clays, silts, and very fine sands) are typically transported as suspended sediment, while particles >1 mm in diameter (coarse sand and larger) typically are transported as bedload (Everest et al., 1987). Particles between 0.1 and 1 mm are usually transported as bedload, but can be transported as suspended load during turbulent, high flow events (Sullivan et al., 1987). The process of saltation, in which particles bounce from the bed up into the water column, blurs the distinction between these two terms. Local hydraulic conditions also can cause shifts in the relative proportion and size classes of bedload and suspended sediment.

Suspended sediment also should be distinguished from wash load. The latter term refers to particles that are washed into the stream during runoff events, and that are finer than the particles found in the stream bed (Ritter, 1978). By definition the wash load is finer than the bed material load, and the wash load is considered to remain suspended the length of the fluvial system (Linsley et al., 1982). Normally the wash load is defined as particles smaller than 0.062 mm (silts and clays). The concept of wash load is rarely used by fluvial geomorphologists or fish biologists, and it is difficult to apply in the type of monitoring studies addressed in these *Guidelines*.

Relation to Designated Uses

Numerous laboratory studies have documented the adverse impacts of fine sediment on benthic invertebrates as well as salmonid reproduction and growth (Chapman and McLeod, 1987). Hynes (1970) characterizes streams with sandy beds as having the lowest species diversity and aquatic productivity. As noted in Section 2.4, fine sediments tend to fill the interstices between coarser particles, and this reduces the habitat space for small fish, invertebrates, and other organisms. An intrusion of fine particles into the bed material also reduces the permeability of the bed material, and this often results in a decline in the concentration of intergravel DO (Section 2.4). Certain invertebrate species are very sensitive to even small declines in DO, and the EPA standards for DO within the water column are set in part because of the sensitivity of invertebrates and salmonid reproduction to the concentration of intergravel DO (EPA, 1986b).

Reduced gravel permeability can inhibit salmonid reproduction by reducing the concentration of DO and by entrapping alevins or fry. In a laboratory study a substrate containing 20% fines was found to reduce emergence success by 30-40% (Phillips et al., 1975). Although other field observations support the basic link between fine sediment and a decline in salmonid reproduction, direct extrapolation of laboratory studies to the field is difficult because (1) changes in suspended sediment typically are accompanied by changes in other environmental factors; (2) different species have varying sensitivity to sediment at different life stages and under different environmental conditions; and (3) changes in behavior may help alleviate the adverse effects of increased sediment (Everest et al., 1987). These same constraints apply to studies relating the concentration of fine sediment to the growth and survival of salmonid juveniles and adults.

An excess of fine sediment can adversely affect habitat availability. The case study of the South Fork of the Salmon River (Box 3, page 17) provides one example, and similar observations have been made on other streams (e.g., Grant, 1986; Cederholm and Reid, 1987; Sullivan et al., 1987). Often, however, pool infilling is due to sand-sized particles which are considered fines by fisheries biologists, but may not be transported as suspended sediment. Thus an increase in the concentration of suspended sediment may not necessarily be correlated with a decreasing bed material particle size.

Direct effects of suspended sediment on salmonids occur only at relatively high concentrations. For example, Noggle (1978) found that the ability of coho salmon fingerlings to capture prey was reduced at suspended sediment concentrations of 300-400 mg L^{-1}. Mortality of salmonids occurs only at concentrations greater than 20,000 mg L^{-1} (Everest et al., 1987).

An increase in suspended sediment concentration will reduce the penetration of light, and a sustained high concentration of suspended sediment could reduce primary production if other factors are not limiting (Gregory et al., 1987; Section 7.2). The effect of suspended sediment on water temperature has not been well documented. EPA's *Quality Criteria for Water* notes that suspended materials will increase heat absorption, particularly in the surface layer, and inhibit mixing between the warmer surface layer and the cooler underlying waters (EPA, 1986b). Others believe that the additional heating due to suspended sediment is negligible because turbid waters have a higher reflectance. The reduced penetration of solar energy caused by an increase in suspended sediment concentration could reduce the solar heating of the bed material, but the attenuation of light energy in water is so rapid that any difference in heating would occur only in areas where the water is less than about 10 cm deep. The practical implications of an increased suspended sediment load on stream temperatures and mixing are limited by the fact that (1) most forest streams are very well mixed, and (2) suspended sediment concentrations typically are very low in summer, which is when high water temperatures are of most concern.

The concentration of suspended sediment also can affect the morphology of alluvial channels. Schumm (1972) classified alluvial streams by the proportion of bedload to suspended load. Streams with 97% or more of the total sediment load as suspended sediment had width-depth ratios <10, and sinuosities >2. In such channels an increase in the suspended load would tend, at least initially, to narrow the channel as the fine sediment is deposited along the banks. Flume studies have shown that an increase in suspended sediment concentrations causes an increase in velocity and a steeper channel gradient (Chang, 1988). An increase in fine sediment may also delay the initiation of bedload transport (Beschta and Jackson, 1979). In general, however, the concentration of suspended sediment has little influence in shaping stream channels (Everest et al., 1987).

Suspended sediment can adversely affect several other designated uses of water. High concentrations of suspended sediment can damage turbines in hydroelectric plants. Suspended matter reduces the value of water for esthetic purposes. For example, it is unacceptable in municipal water supplies for esthetic reasons; moreover, it reduces the efficacy of normal treatment procedures (EPA, 1986b).

Suspended sediment will settle out in still or slow-moving waters, and this can result in clogged irrigation canals and reduced reservoir storage capacity. In some cases, however, the deposition of suspended sediment can be regarded as beneficial. For example, deposition during high flow events provides additional nutrients and soil materials. This regular deposition is a major reason why alluvial valleys often are among the most productive and fertile farmlands.

Effects of Management Activities

Forest management activities can affect the amount of suspended sediment in streams by altering both the erosion rate and the rate of transport into the stream channel. The range of management activities, and the number of erosion and transport processes, have resulted in an extensive literature on the relationship between forest management and sediment yield. However, recent changes in forest management practices may make it impossible to directly extrapolate from previous studies, even if they were conducted in a comparable environment (Everest et al., 1987). The following paragraphs provide a brief summary rather than a comprehensive overview.

Most comprehensive studies of the effects of forest management have found road-building and road maintenance to be a primary source of sediment (e.g., Brown and Krygier, 1971; Megahan and Kidd, 1972). This sediment can be eroded from the road surface (e.g., Reid and Dunne, 1984), from road fills (e.g., Megahan, 1978), or from slope failures associated with road construction and drainage (e.g., Duncan et al., 1987; Megahan and Bohn, 1989). In most cases there is a sharp increase in sediment yield associated with road-building activities, and a rapid decline as roads stabilize (e.g., Beschta, 1978). Increased sediment yields tend to be more persistent if the erosion stems from slope failures or surface runoff associated with continued heavy traffic.

Forest harvest can increase sediment yields by a variety of processes: surface erosion from landings, skid trails, and other compacted areas; slope failures triggered by removal of the tree cover; and surface erosion from burned areas or areas disturbed by site preparation activities (Swanson et al., 1987). Surface erosion can include both fluvial detachment and transport as well as dry ravel and surface creep (Swanson et al., 1987). Historic practices of disturbing the stream channel and removing large woody debris also have been shown to increase the amount of fine sediment in the stream channel (Bilby, 1981; Megahan, 1982). Removal of, or a reduction in, the riparian vegetation is a another mechanism by which forest management activities can increase the amount of fine sediments (e.g., Platts, 1981). Grazing often exacerbates the effect of reducing the vegetative cover by simultaneously trampling the vegetation, compacting the soil, and trampling the streambanks (Gifford, 1981).

In some cases management activities may have no statistically significant effect on suspended sediment concentrations. Some of the key factors controlling the actual increase in suspended sediment are as follows: (1) the intensity of disturbance, (2) the areal extent of disturbance, (3) the proximity of the disturbance to the channel system, and (4) the storm events experienced during the periods when the site is most sensitive to erosion and mass movements (Everest et al., 1987; Swanson et al., 1987). The high natural variability of suspended sediment often makes it difficult to detect a statistically significant increase in suspended sediment from well-planned and properly executed forest harvest operations.

Measurement Concepts

Suspended sediment concentrations are determined by obtaining a water sample, drying or filtering the sample, and then weighing the residual sediment. Concentrations are typically expressed in milligrams per liter (mg L^{-1}), and this usually is equivalent to parts per million (ppm) because 1 L of water has a mass of approximately 1 million milligrams. As sediment concentrations increase, however, the density of water exceeds 1000 g L^{-1}, and this causes an increasing divergence between milligrams per liter and parts per million.

The primary problem with measuring suspended sediment is how to sample in time and space. Estimates of the total amount of suspended sediment over time often are based on a presumed relationship between the concentration of suspended sediment and stream discharge, but this is by no means constant or reliable (e.g., Ferguson, 1986). For example, suspended sediment concentrations for a specified storm event typically are much higher after a dry period than after an earlier, but recent, storm. Often suspended sediment concentrations are higher during periods of increasing discharge (i.e., the rising limb of the hydrograph) and lower during periods of decreasing discharge (i.e., the falling limb of the hydrograph). However, detailed studies indicate that this is not always the case (e.g., Rieger and Olive, 1986; Williams, 1989a). Walling and Webb (1982) discuss how the physical processes of sediment production and yield need to be taken into account to better predict sediment yield and thereby reduce the apparent variability of suspended sediment concentrations.

Suspended sediment concentrations can show considerable spatial variability. The increase in suspended sediment concentration with depth is well known (e.g., Guy, 1970), but the size and concentration of suspended sediment also can vary according to local turbulence and velocity. Thomas (1985) provides a detailed discussion of the concepts and methods of measuring suspended sediment in small mountain streams.

The concentration of suspended sediment also is highly sensitive to the method of sampling. Any sampler disrupts the flow lines, and this can bias the sample. Orifice size, length of the intake nozzle relative to the sampler, and the percent of the sample bottle filled all can influence the accuracy of the sample. The hydraulic requirements of suspended sediment samplers generally preclude sampling within 10 cm or so of the stream bottom (Guy and Norman, 1970), and this limits the accuracy of any attempt to obtain an absolute estimate of suspended sediment flux.

Suspended sediment samplers can be separated into two basic types—point-integrated and depth-integrated. Pointity, gravel permeability, and bed material particle size will be very different.

Assessment

Suspended sediment is a very useful indicator of active erosion in a particular basin. However, the multiple processes involved in sediment storage and delivery preclude the use of suspended sediment concentrations as a quantitative measure of specific hillslope and channel processes. On the other hand, suspended sediment concentrations are very sensitive to landscape disturbance, and its conceptual simplicity gives it broad appeal.

The primary problem with using suspended sediment as a monitoring tool is its inherent variability. Representative samples are difficult to obtain, and suspended sediment concentrations vary tremendously over time and space. Thus it is often difficult to determine if there has been a significant increase in suspended sediment, and whether an observed increase is due to management activities or natural causes. These problems are exacerbated as one moves farther downstream because the impact of individual management activities is diluted and the amount of suspended sediment from other sources becomes larger.

Suspended sediment can and should be included in a monitoring plan provided it is recognized *a priori* that (1) identifying an increase in suspended sediment due to forest management requires several years of background data from the basin or site where management will occur and a similar set of data from comparable, unmanaged site(s); and (2) calculating suspended sediment fluxes and loads results in an inherent uncertainty of at least 25-50%.

Suspended sediment also is just one component of the overall sediment budget. Changes in bedload generally have the greatest geomorphic impact (Section 4.3), but these may or may not be correlated with suspended sediment (Williams, 1989b). Turbidity (Section 4.2) is highly correlated with suspended sediment, but this relationship must be determined for each basin and usually each site. As indicated above, the adverse impact of suspended sediment also is a function of the size distribution of the suspended particles.

4.2 Turbidity

Definition

Turbidity refers to the amount of light that is scattered or absorbed by a fluid (APHA, 1980). Hence turbidity is an optical property of the fluid (Hach, 1972), and an increasing turbidity is visually described as an increase in cloudiness. Turbidity in streams is usually due to the presence of suspended particles of silt and clay, but other materials such as finely divided organic matter, colored organic compounds, plankton, and microorganisms can contribute to the turbidity value of a particular water sample. Since relative proportion, size, weight, and refractive properties of these materials varies considerably, a correlation of turbidity with the weight concentration of suspended matter cannot be assumed (APHA, 1980).

Prior to about 1970 turbidity was measured primarily in Jackson turbidity units (JTU). Jackson turbidity units are determined by slowly increasing the depth of water in a clear cylinder until a candle flame placed under the bottom of the cylinder disappears into a uniform glow (Hach, 1972). Several problems are associated with JTUs: (1) usable range is 25 JTUs and greater; (2) turbidity due to dark-colored particles cannot be measured as too much light is absorbed; and (3) very fine particles are not measured (APHA, 1980). These problems have led to the widespread replacement of Jackson's candle turbidimeter with photoelectric turbidimeters.

Photoelectric turbidimeters measure turbidity in nephelometric turbidity units (NTU); they are able to accurately measure much lower levels of turbidity, and measurements generally are not affected by particle color (Hach, 1972). These properties make photoelectric turbidimeters and NTU units the preferred method for measuring turbidity in streams. The differences in measurement techniques mean that there is no standard conversion between Jackson turbidity units and nephelometric turbidity units (APHA, 1980).

Relation to Designated Uses

Turbidity is an important parameter of drinking water for both aesthetic and practical reasons. A strong public reaction can be expected to a turbid water supply, even if the water technically is safe to drink. However, suspended matter provides areas where microorganisms may not come into contact with chlorine disinfectants, so high turbidity levels may limit the efficacy of normal treatment procedures (EPA, 1986b). Small rural communities may not be able to afford the additional treatment costs necessitated by an increase in the turbidity of their basic water supply (Harvey, 1989).

Turbidity also has a direct detrimental effect on the recreational and aesthetic use of water. The more turbid the water, the less desirable it becomes for swimming and other water contact sports (EPA, 1986b). In many forested areas tourism and recreation are important components of the local economy, and increased turbidity could adversely affect the attractiveness of a water body for fishing, boating, swimming, or other water-related activities.

Most of the biological effects of turbidity are due to the reduced penetration of light in turbid waters. Less light penetration decreases primary productivity, with periphyton and attached algae being most severely affected. Declines in primary productivity can adversely affect the be used as a surrogate for suspended sediment concentrations. The relative ease of measuring turbidity means that qualitative field observations and synoptic sampling can be used to identify specific sediment sources (source-search methodology discussed in Part I, Section 3.2.3).

Turbidity is regarded by many as being the single most sensitive measure of the effects of land use on streams. This is due partly to the fact that relatively small amounts of sediment can cause a large change in turbidity, and partly to the estimated accuracy of turbidity measurements (approximately ±10%) (APHA, 1980; Brown, 1983). Although the variation in turbidity with discharge generally is greater than 10% (Brown, 1983), both the accuracy and variability of turbidity measurements compare favorably with the other sediment parameters (suspended sediment and bedload) as well as the channel characteristics (Chapter 5).

The disadvantages of turbidity are twofold. First, the relationship with suspended sediment must be determined for each site, even though some studies have shown that several sites with similar physical characteristics may have identical relationships. Second, turbidity is highly variable. As in the case of suspended sediment (Section 4.1), turbidity varies according to the discharge; the occurrence of sporadic events such as debris flows, landslides, or the breakdown of log jams; the timing of the sample relative to the season of the year; the time since the last runoff event; and the timing within a storm hydrograph. The range and nonlinear nature of these variations make it very difficult to establish and enforce a narrowly defined turbidity standard for storm events. Narrow turbidity standards are much easier to develop and apply during low flow periods when background levels are consistently low (e.g., a comparison of turbidity levels upstream and downstream of a bridge construction site).

Turbidity measurements are particularly effective in the case of project monitoring (e.g., samples are taken upstream and downstream of a particular management activity).

4.3 BEDLOAD

Definition

Bedload is the material transported downstream by sliding, rolling, or bouncing along the channel bottom (Ritter, 1978). Typically particles >1.0 mm in diameter are transported as bedload, while particles <0.1 mm in diameter are transported as suspended load. Particles between 0.1 and 1.0 mm in diameter can be transported either as suspended load or as bedload depending on the local hydraulic conditions (Everest et al., 1987). Thus even at a single site a particle may be transported as bedload or suspended load depending on the discharge and other hydraulic factors.

Bed material load, a term often confused with bedload, is the transport of particles of a grain size normally found in the stream bed (Linsley et al., 1982). Thus a stream bed comprised primarily of silt and clay particles will have most of its bed material load transported as suspended sediment, while the bed material load of a coarse-bedded stream (e.g., gravels and cobbles) will be transported almost entirely as bedload.

Relation to Designated Uses

Bedload is an important component of the total sediment load of a stream. The proportion of the sediment load transported as bedload varies considerably and cannot be characterized by a simple relationship to suspended sediment load or to discharge (Williams, 1989b).

The amount and size of the bed material, in conjunction with the discharge, slope, and geology, largely determine the overall type and shape of the channel. Wide, shallow channels are characteristic of streams transporting coarse bedload in unconstrained alluvial valleys (Ritter, 1978). As discussed in Sections 5.1-5.2, streams with a high width-depth ratio are more likely to experience high water temperatures that may be detrimental to coldwater fisheries. Streams with coarse bedload tend to have a lower sinuosity than streams that have fine particles as their bed material (Section 5.6.1; Schumm, 1960). Streams with high volumes of bedload and erodible banks often are braided, and the rapid changes in channel location characteristic of braided streams result in continuing high erosion and sediment transport rates. The unstable channels in braided reaches provide relatively poor habitat for salmonids, and the large amounts of sediment transported downstream from braided reaches can adversely affect reservoir storage capacity and other designated uses such as fisheries and irrigation.

Large amounts of easily transported bedload tend to fill in pools and reduce the larger-scale features that are important sources of fish habitat. At very high flows, however, the pools may be scoured (e.g., Campbell and Sidle, 1985).

The type and amount of bedload is very important in determining the amount of microhabitat available for juvenile fish and macroinvertebrates (Section 5.6.1). In general, coarser material provides more habitat space, whereas fine sediments tend to fill up the interstitial spaces between larger particles. Fine sediment is usually defined as particles <0.83 mm in diameter, but some studies have used values of up to 6.4 mm (Everest et al., 1987). The deposition of fine sediment reduces the habitat space for young fish and aquatic macroinvertebrates (Sections 5.6.1, 7.3, and 7.4; Everest et al., 1987).

The deposition of these finer bedload materials (e.g., sand-sized particles) also has been shown to adversely affect gravel permeability and the suitability of the gravel for spawning salmonids (e.g., Everest et al., 1987; Lisle, 1989). A lower permeability usually reduces the concentration of intergravel dissolved oxygen (Section 2.4), and this can be directly related to salmonid spawning success, and the number and diversity of aquatic invertebrates (Chapman and McLeod, 1987).

As suggested above, the deposition of bedload has an adverse effect on reservoir capacity and can clog up irrigation and shipping channels. Hundreds of millions of dollars are spent in the U.S. each year to remove sediment deposited behind dams and in the lower reaches of rivers and estuaries.

Effects of Management Activities

The effect of forest management activities on the availability and transport of bedload has been shown to range from severe (e.g., Megahan et al., 1980) to no significant difference (Moring, 1975; Sheridan et al., 1984). Part of the observed variation in effects is due to the type and intensity of management. In southwest Oregon, for example, clearcutting was found to approximately double the bedload yield as compared to a control watershed, while patch and selection cuts had no apparent effect (Adams and Stack, 1989). The range of erosion and sediment transport processes operating in the Pacific Northwest and Alaska is another reason why widely different results should be expected from different studies, and why simple generalizations cannot be made about the effects of management activities on bedload (Swanson et al., 1987).

As noted in Sections 4.1 and 4.2, forest harvest can increase erosion rates by generating overland flow on compacted areas, increasing the number of slope failures (e.g., Ice, 1985; Megahan and Bohn, 1989), and increasing the rate of dry ravel and soil creep (e.g., Ziemer, 1984). Alterations in the amount of large woody debris (LWD) in the stream channels will alter the sediment storage capacity in the stream channel (Section 5.7; Megahan, 1982). Removal of LWD, or a reduced rate of recruitment of LWD into the stream channel, can result in an apparent increase in sediment yield at the mouth of the basin (Megahan, 1982), even though there may be no net change in the rate of sediment delivered to the stream channel from upslope.

Road construction and road maintenance can increase the amount of bedload by creating areas prone to surface runoff (Reid and Dunne, 1984), altering slope stabilities in cut and fill areas (e.g., Megahan, 1978), and altering drainage patterns in ways that tend to increase the number of landslides and debris flows (e.g., Megahan et al., 1978; Megahan and Bohn, 1989). Similarly, grazing can increase the amount of overland flow and decrease bank stability (Section 5.8; Gifford, 1981). Sand and gravel extraction within the stream channel will alter the channel hydraulics and probably cause a short-term increase in bedload transport until the stream re-establishes a stable channel. Longer-term effects of sand and gravel extraction are difficult to predict.

The material eroded or detached by these different hillslope erosional processes must then be delivered to the stream channel and transported by the stream before it can be measured as bedload. Often significant amounts of material can be stored in the channel (Dietrich et al., 1982). In streams draining the Idaho batholith, for example, 15 times more sediment was stored in the channel than was delivered out of the basin on an annual basis (Megahan, 1982). When evaluating the impact of management activities on bedload, one must also consider whether the material is composed of silt- and clay-sized particles, which probably will be transported as suspended sediment, or coarser particles, which will be transported as bedload.

Extensive studies on the South Fork of the Salmon River in Idaho have attempted to link the effects of forest management and road building to an increase in bedload and the quality of fish habitat. In this basin the combination of management activities, erodible soils, and severe storms has resulted in extensive sedimentation. The large amounts of bedload reduced pool depths and literally buried many of the prime salmonid spawning and rearing areas with sand (Megahan, 1980; Box 3, page 19). In other parts of the Pacific Northwest, studies have documented increased amounts of fine sediment in the bed material in response to forest harvest and road-building (Section 5.6.1; Cederholm et al., 1981; Scrivener, 1988). However, very few published studies have attempted to monitor changes in bedload transport rates due to forest management activities, and then relate these changes to the designated uses of the water body being monitored. The paucity of such studies has strong implications with regard to the relative utility of monitoring bedload transport rates.

Measurement Concepts

The measurement of bedload must be regarded as difficult. Sampling devices disturb the flow in the vicinity of the sampler, and this biases the sample (Guy and Norman, 1970; Emmett, 1980). The most common bedload sampling device, the Helley-Smith sampler, consists of a flared rectangular orifice with an attached mesh bag. The sampler is placed on the stream bottom with the opening facing upstream for a specified time, and the sediment caught in the mesh bag is dried and weighed to get a transport rate in mass per unit time per unit stream width (Helley and Smith, 1971). The most commonly used design has a 76-mm (3.0-inch) square opening and a mesh size for the sample bag of about 0.25 mm. This has been reported to have a catch efficiency of about 1.0 for particles from 0.5-16 mm in diameter (Emmett, 1980). Sampling of larger bedload particles requires a larger sampler, and the catch efficiency is less well known.

Bedload transport rates vary across the stream cross-section, so representative samples should be taken at regular intervals across the stream (Emmett, 1980). Numerous studies, however, have shown that bedload moves in irregular sheets or waves (e.g., Beschta, 1981; Reid and Frostick, 1986). This can be due to migrating dunes or bedforms, and to unpredictable events, such as the breakup of a stream

5. CHANNEL CHARACTERISTICS

INTRODUCTION

The parameters reviewed in this chapter relate to the shape of the stream channel, the structural features within the stream channel, and the stability of the stream banks. These channel characteristics can be monitored on different spatial scales and from different perspectives. For example, bed material particle size and embeddedness evaluate the surface of the streambed on a scale of a few centimeters, whereas a thalweg profile evaluates the topography of the deepest part of the streambed on a scale of tens or hundreds of meters. Measurements of habitat type (e.g., pools, riffles, etc.) were pioneered by fish biologists and are used to evaluate the quality of fish habitat, but these measurements are functionally related to the parameters that might be used by fluvial geomorphologists (e.g., residual pool depth or the number of debris dams caused by large woody debris).

Most of the characteristics of stream channels that might be used for monitoring are controlled by the same basic set of interacting factors. Among the most important of these are the amount and size of sediment, the duration and size of peak flows, slope of the valley bottom, valley bottom width, steepness of the sideslopes, and the local geology. Some of these factors can be considered constant for a given site, while the factors that do vary (discharge and sediment) are relatively difficult to monitor (Chapters 3 and 4). Stream channel characteristics may be advantageous for monitoring because their temporal variability is relatively low, and direct links can be made between observed changes and some key designated uses such as coldwater fisheries.

The importance of these controlling factors suggests that many of the channel characteristics will have a similar response to management activities. Some of the parameters which are most closely related include channel cross-sections (Section 5.1) and channel width/width-depth ratio (Section 5.2); pool parameters (Section 5.3) and thalweg profile (Section 5.4); and the three parameters relating to bed material (particle size, embeddedness, and surface vs. subsurface bed material particle size; Section 5.5). In most cases it is not necessary to monitor each of these closely related parameters, and the selection among these monitoring parameters will depend upon the particular combination of management activities, designated uses, and site-specific conditions. General recommendations are difficult because relatively few studies have used channel characteristics as the primary parameters for monitoring management impacts on streams.

The relatively low temporal variability of channel characteristics must be balanced against (1) the potentially large spatial variability, and (2) the problem of separating man-induced changes from changes due to natural events. Proper statistical design can help alleviate both of these considerations, and the much lower frequency of sampling will allow more sites or more parameters to be measured. In many cases a combination of several channel parameters may be the best approach to evaluate and understand observed changes in the stream channel.

5.1 CHANNEL CROSS-SECTION

Definition

A channel cross-section is a topographic profile of the stream banks and stream bed along a transect perpendicular to the direction of flow. Cross-sectional data are obtained by measuring distance and surface elevations along the designated transect or cross-section. The endpoints of the cross-section are arbitrary, but they should extend at least above the estimated bankfull stage and preferably beyond the current floodplain. If change over time is to be monitored, the elevation data must be related to a permanent benchmark.

Relation to Designated Uses

A decrease in channel depth and an increase in channel width can have major adverse effects on the biological community. A decrease in depth tends to reduce the number of pools (Beschta and Platts, 1986), and this will reduce certain types of fish habitat. An increase in stream width will lead to an increase in net solar radiation and higher summer water temperatures (Beschta et al., 1987). The combination of shallower pools and increased solar radiation can greatly affect the suitability of the stream for coldwater fisheries. An increase in stream width and an increase in light penetration is likely to increase primary production, although this may be partly offset by a reduced input of organic debris into the aquatic ecosystem from the riparian zone (Gregory et al., 1987).

An increase in channel width is achieved through bank erosion and a corresponding increase in sediment inputs into the stream channel. An increase in bank erosion is particularly important because the sediment is delivered directly into the stream channel (Section 5.8). The adverse effects of an increased sediment load were reviewed in Chapter 4.

An increase in the riparian canopy opening due to an increase in stream width can have a series of adverse biological effects. Such an increase is likely to reduce the amount of riparian vegetation, and this will reduce the ability of the riparian zone to capture nutrients and sediment (Section 6.2). The riparian zone is also a major source for large woody debris, an important element in pool formation and habitat diversity in most forested streams in the Pacific Northwest and Alaska (Section 5.7).

Response to Management Activities

Forest harvest, road building, road maintenance, and other management activities often increase the amount of sediment delivered to the stream channel. Usually an increase in coarse sediment will lead to an accumulation of sediment in the deeper parts of the stream channel. If the runoff remains unchanged, an unconstrained stream generally responds by increasing its width (e.g., Lisle, 1982; Grant, 1988). Although the magnitude of this increase in width will be affected by the valley shape and the bank materials, Lisle (1982) observed increases in width even in constrained, non-alluvial materials. Thus changes in width or the width-depth ratio can be used as an indicator of a change in the relative balance between the sediment load and the sediment transport capacity.

Grant (1988) noted that an increase in channel width also could result from an increase in the size of peak flows. As shown in Section 3.1, increases in the size of peak flows due to forest harvest generally are small except in areas subject to rain-on-snow events. This additional mechanism for channel widening does not preclude the use of channel width as a monitoring technique, but it does suggest that additional data are required to understand the cause of any observed changes. Harvest of the riparian vegetation also can decrease bank and channel stability and thereby initiate a cycle of bank erosion and channel widening (Section 6.2).

Measurement Concepts

The determination of channel width and channel depth is problematical because both parameters are flow-dependent. Depth tends to increase with flow more rapidly than width (Dunne and Leopold, 1978; Leopold and Maddock, 1953), but this relationship may not be constant at a given cross-section. A stream with a wide, flat floodplain, for example, will experience a sudden increase in width when the flow overtops the banks and spreads across the floodplain. Thus the monitoring of changes in width and depth should be done at specified discharges and locations. A geomorphically based discharge, such as active channel width or bankfull width, is most commonly used but may be relatively subjective. The resulting uncertainty must be taken into account when drawing inferences from the data.

Cross-section location will affect the width-depth ratio and, as noted in Section 5.1, the sensitivity to change. For example, stream width and width-depth ratios are likely to differ across riffles, sharp bends, and pools. This variation can be minimized by measuring widths and depths at a consistent channel form such as straight riffle reaches, using average depth rather than maximum depth, or by using average values obtained from several different cross-sections.

The sensitivity of stream width and width/depth ratios to management impacts and natural events will vary with stream type and location. A bedrock stream in a steep, V-shaped valley will not alter its width in response to an increase in sediment load as easily as a stream in a wide valley with unconsolidated alluvial sediments. Channel shape is also affected by the relative proportions and absolute amounts of bedload and suspended load (e.g., Schumm, 1960). Streams with cohesive materials tend to have narrow, deep channels, while streams in a sandy or other non-cohesive substrate tend to be wide and shallow.

Standards

No standards have been set or proposed for changes in stream width or width-depth ratios.

Current Uses

Although a considerable amount of cross-section data can be obtained from gaging stations, stream inventories, and other studies, channel width has not been extensively used as a monitoring technique. Powell (1988) documented the increase in stream width that occurred in both the careful and the intense logging treatments on Carnation Creek in coastal British Columbia. Channel width and depth data also have been collected in conjunction with the intensive, long-term monitoring effort on the South Fork of the Salmon River (Box 3, page 19; Torquemada and Platts, 1987).

Present efforts by agencies such as the U.S. Forest Service to inventory fish habitat and stream channel condition should generate a large amount of stream width and width-depth data. It remains to be seen how well these particular parameters can define stream condition and monitor management impacts.

Assessment

On-the-ground measurements of channel widths and width-depth ratios have the potential of being relatively sensitive indicators of changes in the size of peak flows and sediment yields. Channel width and width-depth ratio can be related to the value of streams for fish and recreation.

Defining channel width and depth in the field is not a trivial problem. For this reason it is best to monitor channel width at a series of cross-sections. Use of geomorphic indicators such as bankfull width or active channel width must be done with great care, as these tend to be subjective and a major runoff event can alter the channel cross-section and make identification of bankfull features questionable. Determining width and depth at a standard discharge may be logistically difficult unless it is done at an existing gaging station. The problem with using gaging stations as monitoring locations is that they usually are placed at geomorphically stable locations and are relatively insensitive to management-related changes in channel form.

Measuring channel width or width/depth ratios also suffers from the same basic limitation as any other instream measure—namely, that it does not provide any information on the cause of an observed change. Hence monitoring data must be combined with information on management activities, storm events, and sediment sources (e.g., roads, debris flows, landslides, or a breakdown of debris dams). As noted earlier, one also has to put the changes observed from a relatively short-term monitoring project into the context of larger changes such as extreme floods or major sediment inputs. Only with this additional information can the effects of forest management begin to be deciphered.

Finally, the magnitude and rate of change in channel width and width-depth ratio will depend on factors such as the slope of the stream, the shape of the valley bottom, the bank and bed materials, and the recent flood history. Although this may make it difficult to establish specific standards, it should not mask general trends. These considerations also indicate that long-term measurements at various locations within the watershed are needed for adequate monitoring.

5.3 POOL PARAMETERS

Definition

Pools can be defined as sections of the stream channel that have a concave profile along the longitudinal axis of the stream, or as areas of the stream channel that would contain water even if there were no flow. This means that the maximum depth of pools is deeper than the average thalweg depth, and water velocities at low flows often are lower than the average velocity. Pools are an important component of the aquatic habitat, and they can be classified and measured in several different ways.

Pools usually are classified by the process that created the pool (e.g., undercut bank, debris dam, beaver dam, plunge pool, etc.). This classification is useful for evaluating the abundance and type of fish habitat (Bisson et al., 1982), although the various categories of pools and other habitat types have not been standardized (Section 5.5; Platts, 1983). Nevertheless, the number and type of pools in a particular reach could be enumerated, and changes over time could be monitored.

More commonly the depth, residual depth, volume, or area of pools are measured, and these measurements can be used as monitoring parameters. Pool depth can be either average depth or maximum depth. Residual pool depth refers to the depth of the pool below the downstream lip of the pool (i.e., the depth of the water which would be trapped in the pool if there was no discharge) (Lisle, 1987). Pool area refers to the total surface area of the pool. Both pool depth and pool area will vary with discharge, whereas residual pool depth is not discharge-dependent.

Relation to Designated Uses

Pools are an important morphological feature in stream channels and an essential type of fish habitat. In general, a variety of pool types are needed to provide the range of habitat needed by different species and age classes of fish. Slow-moving dammed or backwater pools may be necessary for salmonid survival under harsh winter conditions. Deep undercut pools may provide protection from high temperatures. Young fish may require shallow, low-quality pools to avoid predation. Particularly in smaller streams, pools provide the majority of the summer rearing habitat (Beschta and Platts, 1986). Pools also may be important sites for recreational activities such as fishing and swimming.

Response to Management Activities

Those pools characterized by low flow velocities (e.g., backwater or dammed pools) are particularly susceptible to infilling with sediment. Hence the depth, area, or volume of these pools can serve as a relatively sensitive indicator of changes in the coarse sediment load due to forest harvest, road building and maintenance, mining, or other management activities. On the South Fork of the Salmon River logging and road maintenance caused an influx of sand-sized material that filled in many of the prime salmonid spawning and rearing areas (Megahan et al., 1980).

Changes in pool area, pool volume, or residual pool depth also can be caused by changes in the features that create pools. Thus a reduction in the input of large woody debris may lead to a reduction in the number and size of pools (Section 5.7). Similarly, a change in the size or frequency of peak flows will alter the ability of the stream to transport coarse sediment, and this may alter pool measurements.

The total area, depth, or frequency of pools may not always be a reliable indicator of adverse management effects. Streams immediately downstream of active glaciers, for example, usually are braided and have little or no pool areas. Landslides, debris flows, and other mass movements typically result in a loss of pool area and volume, and these pulsed inputs of sediment may or may not be triggered by management activities (Swanson et al., 1987).

Measurement Concepts

Pool depth, pool area, and pool volume are all direct physical measurements, and they are relatively simple to make in small streams. Recent publications have encouraged the use of visually estimating the width, depth, or area of pools within a stream reach, and then adjusting these visual estimates for any systematic bias by measuring a certain percentage of the pools (Hankin and Reeves, 1988). In larger streams with deeper pools, direct measurements are considerably more difficult. Also, a series of conceptual problems in making pool measurements must be considered before embarking on a classification or monitoring program.

First, it may be difficult to determine exactly what constitutes a pool. Large, still pools are easy to classify, but the change from pools to runs or glides is one point on a continuum. Platts et al. (1983) found a consistent observer bias when measuring pool areas along stream cross-sections. This consistent bias resulted in a relatively narrow 95% confidence interval for the data (±10%), but poor year-to-year accuracy and precision.

A second problem associated with pool measurements is that pool depth, pool area, and pool volume are all flow-dependent. An increase in stage will increase the value of these parameters. Although this may not be a problem in streams with a consistent summer baseflow, it does mean that stage or water depth must be recorded and taken into account when analyzing the data. The advantage of residual pool depth is that it is independent of discharge (Lisle, 1987).

Similarly, the classification of pools and other habitat types is stage-dependent, but this fact is often ignored (Section 5.5). At higher flows a pool may become a run, or a pocket water may become a riffle. Hence any summary statistics on pool-riffle ratios or the frequency of pool types also must consider the discharge at the time the data were collected. For this reason comparisons between surveys must be done with extreme caution.

Standards

No standards for any pool parameters have been established or proposed.

Current Uses

Most surveys of fish habitat or stream channel condition have utilized some measure of pool area, length, depth, or volume. Many of these surveys also identify the primary cause of each pool. These data are then used to generate summary statistics on the pool-riffle ratio, pool area, or pool volume per unit length of stream channel. The expectation is that subsequent surveys should be able to determine whether substantial shifts have occurred in these values. Alternatively, one could monitor changes in individual pools, but this approach assumes that the pool-forming structure is constant in time. Studies of woody debris in streams indicate that the larger pieces are relatively stable (Sedell et al., 1988), but it would be prudent to monitor at least several pools of as many different types as possible.

Pool parameters probably are most useful in alluvial channels. Studies of stream channel development following the Mount St. Helens eruption indicate that in many reaches a riffle-pool geometry developed after only a couple of years (Meyer and Martinson, 1989). This suggests that pools could be used for monitoring even under relatively high sediment loads. Pool parameters are unlikely to be useful in bedrock channels that are regularly scoured by high flows.

Assessment

In many streams, pool parameters have considerable potential for monitoring. Decreases in pool depth or pool volume may be relatively sensitive indicators of logging-induced changes in the coarse sediment load or the size of peak flows. Since pool parameters have not been extensively monitored in the past, there is little documentation to guide the selection of a particular parameter. Residual pool depth does have the advantage of being independent of discharge. Residual pool depth also may be the most sensitive pool parameter, as an increase in coarse sediment is likely to first affect pool depth. Monitoring pool parameters will be most useful in low or moderate gradient streams in alluvial valleys (Everest et al., 1987).

that include subsets of the major habitat types (riffles and pools) because this more detailed classification system may provide more insight into the suitability of the stream for different fish species.

As noted earlier, habitat composition varies with discharge, and this must be considered when undertaking stream surveys. Observers should be given similar training in order to ensure consistency. Repetitive surveys should be conducted by the same people wherever possible in order to eliminate any bias between surveyors. If specific habitat units are being monitored, particular care must be given to defining the boundaries between adjacent habitat units, as demarcation errors will reduce the accuracy of the procedures and hence the ability to detect change (Platts et al., 1983).

At this point there are little or no data to indicate whether it is best to monitor individual habitat units or to utilize summary statistics for a stream reach. Some researchers posit that changes in the sequence of habitat units may be one of the most sensitive and revealing monitoring techniques that can be derived from habitat unit surveys.

Standards

Currently there are no regulations or standards for habitat composition. In some National Forests pool-riffle ratios are being monitored, and a decline in this ratio is considered an adverse management effect. Often a pool-riffle ratio of 1:1 is considered optimal, but the limited literature suggests that this is highly variable among streams and fish species, and should not be utilized as a standard (Platts et al., 1983).

Current Uses

An inventory of habitat units usually is conducted to assess the suitability of the stream for fishery resources. Unfortunately, "ideal" conditions are difficult to define and are likely to vary widely according to the fish species of interest, the flow regime, and other environmental factors. Hence we may be able to identify stream reaches that have clearly been impacted by land management activities and offer poor quality habitat for salmonids, but it may not be possible to clearly rank streams classified as "acceptable." Thus one benefit of conducting habitat surveys will be a better understanding of the existing variability of habitat units among streams. To the extent that fish census data are available, and other factors such as fishing pressure can be accounted for, it should be possible to better define "ideal" habitat conditions.

Use of habitat units for monitoring environmental change has not been extensively tested because of the paucity of long-term data. Extensive stream surveys that estimate or measure each habitat unit only recently have been initiated in Washington, Oregon, and Idaho by agencies such as the U.S. Forest Service. Much of the data have not yet been analyzed, but the results are expected to document a large amount of variability in undisturbed streams. Subsequent surveys will be needed to determine what level of change is acceptable and how to distinguish changes due to land management activities from changes due to natural causes. A few repeat surveys have at least indicated that survey data are consistent (S. Ralph, Univ. of Washington; D. Bates, Gifford Pinchot Natl. Forest; and G. Luchetti, King County, WA, pers. comm.).

Assessment

Habitat unit surveys provide a useful, quantitative characterization of stream channels. At this point, however, our ability to classify and measure habitat units probably exceeds our capability to interpret the results. This should change as comparative data become available and the results of individual surveys are linked to land management activities. As with other geomorphic parameters, it may prove difficult to separate land use effects from the effects of natural events.

Habitat unit surveys may be relatively insensitive to land use practices. A small amount of sediment, for example, might significantly alter the bed material (Section 5.6) or residual pool depth (Section 5.3), but might not alter the size of, or ratios among, different habitat units. We should expect that different habitat units will exhibit differences both in their sensitivity to change, and in their recovery rate once change does occur. More experience is needed to determine if it is better, for example, to directly monitor pool parameters (Section 5.3) or large woody debris (Section 5.7) rather than habitat units. In view of this uncertainty, current efforts to conduct large-scale habitat unit surveys must be viewed with some concern.

In summary, habitat unit surveys are important to improve our knowledge of the relationship between aquatic life, fish production, and stream channel morphology. By then linking habitat data to land use activities and climatic events, we can better define optimal conditions and susceptibility to change. At present, however, we do not have the experience or data to fully assess the potential of habitat unit surveys as a monitoring technique.

5.6 Bed Material

5.6.1 Particle-Size Distribution

Definition

The composition of the material along the stream bed is a very important feature of stream channels. The most common method to characterize the bed material is to classify it by particle size. By taking a sufficiently large sample, one can construct a plot of particle size versus frequency in percent.

Different points in the particle-size distribution are used to provide a simple characterization of the bed material. Common variables include the median particle size (d_{50}) and d_{84}, which is the particle diameter equal to or larger than 84% of the particles (clasts) on the channel bottom. The d_{84} and d_{16} are used to describe the variability of the particle-size distribution around the mean because they are each one standard deviation away from the mean when the data are transformed onto a logarithmic scale.

Another approach to evaluating the bed material is simply to estimate or measure the percent of the bed surface covered by fine particles. The size limit for fine particles will vary by location and purpose of the monitoring, but usually ranges between 2 and 8 mm in diameter. This approach implicitly assumes that fine sediment is of primary concern, and it is not necessary to determine the size distribution of the coarser bed materials.

Chapman and McLeod (1987) conclude that the fredle index shows some promise as a measure of gravel suitability for salmonid spawning in the Northern Rockies. The fredle index is defined as d_g/s_g, where d_g is the geometric mean particle size, and s_g is the geometric standard deviation (Lotspeich and Everest, 1981).

Relation to Designated Uses

The particle size of the bed material directly affects the flow resistance in the channel, the stability of the bed, and the amount of aquatic habitat (Beschta and Platts, 1986). Because the flow resistance is one part of the overall energy loss in streams, the mean particle size can be related to the other factors that control energy loss in streams such as the stream gradient (Hack, 1957) and the sinuosity.

Although a direct relationship exists between the size of the bed material and the stability of the bed, other factors such as the slope, depth, local turbulence, and bank characteristics will affect whether a particular particle will be moved. The frequency of bedload transport is of critical importance for fish spawning and the other organisms utilizing the stream bottom for cover, foraging, or as a substrate.

The size of the bed material also controls the amount and type of habitat for small fish and invertebrates. If the bed is composed solely of fine materials, the spaces between particles are too small for many organisms. Coarser materials provide a variety of small niches important for small fish—especially juvenile salmonids—and benthic invertebrates. Coarser materials also have more interflow through the bed, effectively expanding the suitable habitat for benthic invertebrates and other organisms down into the stream bed, and facilitating salmonid reproduction. Platts et al. (1979) found a close relationship between geometric mean particle size and gravel permeability. Hence a decrease in the median particle size of bed material will decrease the permeability of the bed material, and this will tend to decrease intergravel dissolved oxygen (DO) concentrations. Even a small decline in intergravel DO can severely affect the survival of salmonid eggs, alevins, and invertebrates (Section 2.4).

Effects of Management Activities

One of the most common and probably the most damaging effect of forest management activities is to decrease the median bed material particle size. Forest harvest, road building and maintenance, and placer mining all tend to increase erosion and sediment delivery rates (Swanson et al., 1987). Most of the material reaching the stream channel as a result of human activities will be sand-sized or smaller. The deposition of this material in the stream channel then has a series of adverse effects (Chapter 4; Everest et al., 1987).

There is some evidence that an increased deposition of fine materials may be partially self-perpetuating. In some cases the onset of bedload transport is delayed when the interstitial spaces are filled with fine sediment (Reid et al., 1985). A reduced frequency of bedload transport then provides more opportunity for the deposition of fine particles and fewer opportunities for fines to be washed out during high flows (Beschta and Jackson, 1979).

Measurement Concepts

The characterization of bed material has been the subject of considerable study. Pebble counts are used to develop a particle size distribution for the bed surface material, while bulk samplers are used to determine the particle size distribution in the surface or subsurface. The selection of a measurement technique depends on the time and equipment available, as well as on the objectives of the sampling.

Pebble counts are a systematic method of sampling the material on the surface of the stream bed (Wolman, 1954). Typically a grid or transect is established, and the sizes of 100 or more particles are tabulated to establish a frequency distribution. Since each sampled particle represents a portion of the bed surface, the frequency distribution represents the percent of the stream bed covered by particles of a certain size, and not the percent by volume or weight. Particles smaller than 2-4 mm are difficult to measure in the field and may be classified only as fines (Wolman, 1954). Other studies estimate the size of fine particles by feel or comparison to reference samples. Pebble counts are simple and rapid, but there may be some bias against selecting very small or very large particles.

A second approach to determining the particle-size distribution of the bed material is by obtaining and sieving bulk samples. A McNeil sampler is the most common means to obtain a bulk sample. The McNeil sampler is a metal, tube-shaped device that is driven into the streambed to the desired sampling depth. Coarse material within the sample tube is extracted by hand. By capping the tube when extracting the corer most of the fine sediments are retained (McNeil and Ahnell, 1964; Platts et al., 1983). The other major technique to obtain a bulk sample is to freeze a sample of the bed material using liquid CO_2 or liquid nitrogen. The frozen sample is then thawed and sieved in order to obtain the particle size distribution. One major advantage of frozen cores is that they retain the vertical structure in the sample, thereby permitting comparisons between particle-size distributions at different depths (Section 5.6.3). Platts et al. (1983) discuss both these techniques in detail and conclude that (1) neither the McNeil sampler nor the freeze core technique is adequate when substrate particles larger than about 25 cm are present, and (2) neither takes a completely representative sample.

One difficulty with evaluating the extensive literature on bed material particle size is the variation in the systems used to classify particle sizes. Some investigators have used many size classes, while others have used as few as six size classes (Platts et al., 1983; Chapman and McLeod, 1987). Each size class can be associated with a specific term (e.g., sand, gravel, cobbles, boulders), but these terms are not necessarily consistent (Platts et al., 1983). The most common classification system in the U.S. is presented in Table 9. A classification commonly used in the scientific literature is the phi index, where phi = $-\log_2 d$, with d being the particle diameter in mm. Use of the phi index normalizes the particle-size distributions so they can be analyzed using parametric statistics and plotted directly on arithmetic graph paper (Wolman, 1954).

The selection of the sampling technique should be determined by the objectives of the sampling. Characterization of the bed material can be done most easily by using Wolman pebble counts or by measuring the percent of the bed surface covered by fines. McNeil core samples and freeze cores both are useful in assessing the suitability of the substrate as spawning gravel. Freeze cores can be used to determine the variation in the particle-size distribution with depth. Comparisons between the surface and subsurface samples may indicate a change in the sediment load (Dietrich et al., 1989; Section 5.6.3).

Standards

Currently there are no existing or proposed standards for bed material particle size. The state of Idaho has been considering the use of percent of fines on the bed surface as a criterion, but this was rejected because the percent of fines on the bed surface could not be directly linked to specific designated uses of water (Harvey, 1988).

Current Uses

Bed material particle size has been used extensively in research, stream classification, stream inventories, and stream monitoring. Some monitoring projects have successfully used visual estimates or photographic comparisons to estimate particle size or percent fines (e.g., Megahan et al., 1980). Generally visual techniques are less sensitive and less reliable than the more systematic and quantitative sampling methods (Chapman and McLeod, 1987).

Both pebble counts and McNeil core samples have been used extensively by the U.S. Forest Service to inventory and monitor stream condition, but the resulting data remain largely unpublished. Long-term studies on the effectiveness of bed material particle size as a monitoring technique are surprisingly scarce, although a number of studies have investigated the effect of logging on bed material particle size with varying results (e.g., Platts and Megahan, 1975; Megahan et al., 1980; Sheridan et al., 1984; Scrivener, 1988). Probably much of this variation in results is due to the different geologies and stream characteristics. Bed material particle size is probably less appropriate as a monitoring technique in areas where clays and silts predominate, or in very steep gradient streams.

Table 9. Classification of bed material by particle size (adapted from Platts et al. 1983).

Class name	Size range: Millimeters	Size range: Inches	ϕ*
Very large boulders	4,096 - 2,048	16 - 80	-12 - (-11)
Large boulders	2,048 - 1,024	80 - 40	-11 - (-10)
Medium boulders	1,024 - 512	40 - 20	-10 - (-9)
Small boulders	512 - 256	20 - 10	-9 - (-8)
Large cobbles	256 - 128	10 - 5	-8 - (-7)
Small cobbles	128 - 64	5 - 2.5	-7 - (-6)
Very coarse gravel	64 - 32	2.5 - 1.3	-6 - (-5)
Coarse gravel	32 - 16	1.3 - 0.6	-5 - (-4)
Medium gravel	16 - 8	0.6 - 0.3	-4 - (-3)
Fine gravel	8 - 4	0.3 - 0.16	-3 - (-2)
Very fine gravel	4 - 2	0.16 - 0.08	-2 - (-1)
Very coarse sand	2.0 - 1.0	0.08 - 0.04	-1 - (0)
Coarse sand	1.0 - 0.5	0.04 - 0.02	0 - 1
Medium sand	0.50 - 0.25	0.02 - 0.01	1 - 2
Fine sand	0.250 - 0.125	0.01 - 0.005	2 - 3
Very fine sand	0.125 - 0.062	0.005 - 0.0025	3 - 4
Coarse silt	0.062 - 0.031	-	4 - 5
Medium silt	0.031 - 0.016	-	5 - 6
Fine silt	0.016 - 0.008	-	6 - 7
Very fine silt	0.008 - 0.004	-	7 - 8
Coarse clay	0.004 - 0.0020	-	8 - 9
Medium clay	0.0020 - 0.0010	-	9 - 10
Fine clay	0.0010 - 0.0005	-	10 - 11
Very fine clay	0.0005 - 0.00024	-	11 - 12

*phi.

Assessment

Bed material particle size may have considerable promise for monitoring purposes as it appears to be relatively sensitive to changing sediment loads (e.g., Megahan et al., 1980; Platts et al., 1989). Additional effort is needed to more precisely define the parameter(s) to be monitored, to strengthen the link between bed surface particle size and various designated uses, and to determine the environments in which a bed material parameter is most useful.

The selection of a bed material monitoring parameter should consider whether a complete particle size distribution is needed, or whether a single number, such as the d_{50} or percent fines, will suffice. Chapman and McLeod (1987) suggest that geometric mean particle size and percent of the bed surface covered by fines should both be used to define habitat quality.

Sampling locations also need to be clearly defined. An ideal sampling location has a high sensitivity to management impacts and minimal response to natural events. Since these two criteria are likely to be in conflict, detailed studies are needed to determine the most appropriate sampling location(s) within a stream channel. Some studies suggest that percent fines should be evaluated within the egg pockets of salmonid fishes, as these have the lowest variability and the most direct link to a designated use (spawning success of coldwater fishes) (Chapman and McLeod, 1987).

Chapman and McLeod (1987) reviewed the linkages between bed material particle size and quality of fish habitat. Large amounts of fine sediment clearly are detrimental to salmonid reproduction and rearing, but quantitative relationships at lower levels of fine sediment are more difficult to establish (Everest et al., 1987). These quantitative relationships also are likely to vary among ecoregions, suggesting a need for varying standards or criteria.

In some areas, bed material particle size may not be a useful monitoring parameter. Steep headwater streams, streams with a clay substrate, and low-gradient rivers all may exhibit little change in their bed material particle-size distribution despite a changing sediment load.

The timing of sampling also may affect the results. At high flows the finer particles tend to be flushed or washed from a coarse-bedded stream. Hence sampling immediately after a high flow may indicate a coarser streambed surface than sampling after a relatively quiescent period (Adams and Beschta, 1980).

These constraints in using bed material particle size for monitoring may be alleviated by combining particle size data with other channel parameters. Monitoring of bed material particle size, for example, might be done on selected cross-sections or in selected pools and riffles within a thalweg profile. This would permit changes in bed material to be more directly linked to deposition or scour, as well as to changes in the quality and amount of fish habitat. Monitoring bed material particle size within cross-sections or a thalweg profile also simplifies the problem of identifying sampling sites. In general, a combination of techniques will facilitate cross-verification and our understanding of stream response to management activities.

5.6.2 EMBEDDEDNESS

Definition

In streams with a large amount of fine sediment, the coarser particles tend to become surrounded or partially buried by the fine sediment. As shown in Figure 8A, embeddedness quantitatively measures the extent to which larger particles are embedded or buried by fine sediment. The measure was first used to quantify stream sedimentation in the 1970s and early 1980s (Klamt, 1976; Kelly and Dettman, 1980). Since then the method has undergone a series of modifications and has been used as an indicator of the quality of over-wintering juvenile salmonid habitat (Munther and Frank, 1986; Burns and Edwards, 1987; Torquemada and Platts, 1988; Potyondy, 1988). The method and its application continue to be improved and standardized by researchers in Idaho (Skille and King, 1989) and Montana (Kramer, 1989).

Currently variation exists in the suggested minimum and maximum size of rocks to be measured and in the specific feature being measured. Most researchers define the technique as cobble embeddedness, even though measurements typically are made on all rocks with a primary axis between 4.5 cm (very coarse gravel) and 30 cm (small boulders). Torquemada and Platts (1988) modified the method to measure rocks as small as 1.0 cm, and the inclusion of these smaller particles led them to use the term embeddedness rather than cobble embeddedness.

The difficulty in measuring cobble embeddedness and the high variability of individual measurements have stimulated research into a series of related measurements. One alternative is to measure the height of the rocks above the bed surface, and this is termed "total free space" (Fig. 8B). Conceptually this is similar to bed roughness, and it is an indicator of the area protected from the current. Such areas are important fish rearing and macroinvertebrate habitat. This measurement also has been termed "living space" by Skille and King (1989) and "interstitial space" by Kramer (1989).

To reduce the variability associated with measurements from individual particles, Kramer (1989) suggested that the total free space from all particles within a specified sample area (typically a 60-cm diameter circle) be summed and then divided by the area sampled. This was termed the "interstitial space index" (ISI), where

$$ISI = \Sigma D_f / Area.$$

ATTACHMENT # 5

Legend

- Cumulative Effects Analysis Boundary
- Subdrainage Boundary
- (28) Subdrainage Number
- North Fork Coeur d'Alene River
- (95) Riffle Armor Stability Index (RASI) Values on the North Fk. Coeur d'Alene River
- Skookum Planning Area

ROS, ECA, and PF by Subdrainage:

ROS — Rain On Snow High Factor

ECA — Equivalent Clearcut Area (% of watershed area)

PF — Spring Peak Flows (% above background)

Subdrainage	ROS	ECA	PF
1	1.33	17.6	7.6
2	1.06	11.8	4.6
3	1.16	9.9	4.2
4	1.18	20.0	8.4
5		9.7	4.1
6	1.22	20.7	8.5
7	1.11	33.0	13.6
8	1.12	24.6	13.0
9	1.29	18.3	7.7
10	1.24	13.7	5.7
11	1.15	21.5	9.0
12	1.07	14.7	6.1
13	1.03	5.6	2.3
14	1.33	11.9	5.0
15	1.25	12.0	5.1
16	1.20	14.9	6.2
17	1.29	24.7	10.4
18	1.18	14.6	6.1
19	1.22	21.0	9.2
20	1.13	17.7	7.5
21	1.23	13.5	5.2
22	1.37	22.9	9.6
23	1.28	26.0	10.9
24	1.33	22.3	9.4
25	1.14	14.6	6.1
26	1.15	20.1	8.4

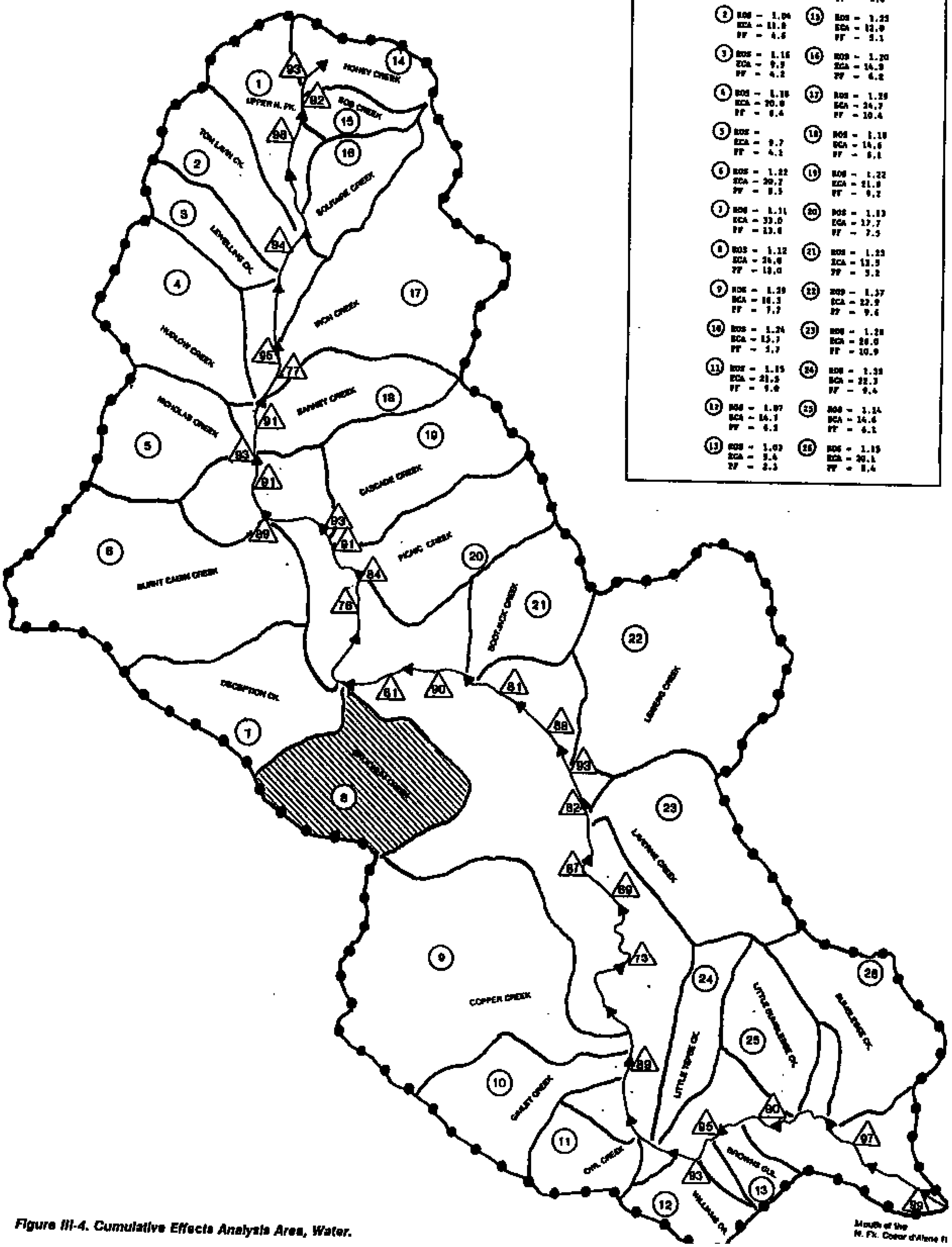

Figure III-4. Cumulative Effects Analysis Area, Water.

IDAHO PANHANDLE NATIONAL FORESTS
MONITORING PROJECT SUMMARY SHEET

Type of Monitoring: Effectiveness (Beneficial Uses)

District: Forest-Wide

Project Name: Validation of Fish Habitat Trends

Site Location: Spokane River Basin above Post Falls

Objectives: Establish baseline fish habitat type occurance, frequency,and distribution in entered and unentered watersheds.

Parameters: Habitat type, length, width, residual pool depth, residual pool volume, Riffle Armor Stability Index (RASI), substrate, pool complexity, and stream temperature.

Summary of Results

With the exception of Loop Creek and Indian Creek all tributaries in the St. Joe Drainage, on Forest Service managed lands above Calder, were habitat typed. Additional tributary streams in the Coeur d'Alene, Pack River, Priest River and Moyie River drainages were also typed. Eight streams in the upper St. Joe Drainage were determined to be unentered and data from them were combined and stratified by stream order and channel type to provide a basis for evaluating any changes in habitat quality or quanity between entered watersheds relative to habitat parameters.

An evaluation of data collected from unentered and entered watersheds in the St. Joe Watershed suggest the following changes in fish habitat have occured. In "A" channels of unentered watersheds fish habitat is dominated by pocket water (55%) and riffles (32%). Entered watersheds show a significant reduction in pocket water (9%) with an increase in riffle habitat (52%) and braided habitat (11%) in "A" type channels **(Figure 1)**. Residual pool volumes and depths of pools in first order "A" channels of entered watersheds had been reduced by 7% and 23% respectively **(Figures 2,3)**. In second order "A" channels of entered watersheds residual volumes and depths of pools had been reduced by 22% and 27% respectively relative to unentered watersheds **(Figures 4,5)**.

In "B" channels major reductions of pool habitat both in terms of pools by percent length of stream and residual depth and volume were observed in entered watersheds relative to unentered watersheds. In entered watersheds, second order "B" channel lineal pool habitat was reduced in length by 42% **(Figure 6)**. Residual pool volume and depth were reduced by 51% and 17% respectively **(Figures 7,8)**.

Physical fish habitat data from entered watersheds in the Coeur d'Alene Basin was evaluated by comparing it to physical fish habitat data from unentered watersheds in the St. Joe Drainage because data from unentered watersheds in the Coeur d'Alene are not available. Residual pool depth and volume of pools in first order "A" type channels of entered watersheds showed a 28% and 19% loss relative to pools in "A" type channels of unentered watersheds **(Figure 9, 10)**. Coeur d'Alene "B" type channels, in entered watersheds, showed a complete loss of pocket water and a 50% loss of lineal pool habitat **(Figure 11)**. Residual pool depth and volume in pools found in "B" channels of entered watersheds in the Couer d'Alene basin showed a 30% and 67% loss respectively relative to pools in "B" channels of unentered watersheds in the St Joe Drainage **(Figures 12,13)**.

To address the implications of these data it is important to digress for a moment and review the habitat requirements and ecology of salmonids and the cutthroat and bull trout in particular. Habitat requirements of cutthroat trout and bull trout vary by age and season of the year (Baltz et al 1991; Moore and Gregory 1989; Rieman and Apperson 1989; Campbell and Neuner 1985). Young-of-the-year fish initially seek stream margins with heterogeneous habitat structure; where this habitat is not present or lost, juvenile trout populations are virtually eliminated (Moore and Gregory 1989). Dolloff and Reeves (1990) reported the young Dolly Varden (Salvelinus malma) most frequently used woody debris as cover. As fish grow larger and mature they seek out deep water habitat types such as pools and deep runs (Baltz et al 1991; Hickman and Raleigh 1982). During winter cutthroat trout typically seek deeper water associated with large woody debris and may spend more than 75% of their life history associated with pools (Moore and Gregory 1989).

There is strong evidence that shifts away from channel equilibrium can result in negative changes in the structure and function of stream ecosystems (Bilby and Likens 1980; Schlosser 1982) and reduce their dependent fish populations. Bisson and Sedell (1982) reported that where stream channels had become destabilized riffles elongated and in many cases extended through former pool locations resulting in loss of pool volume and large stable debris for cover. They suggested that declines in older fish may have resulted due to their dependency upon deeper water habitats.

The function of headwater streams and their importance to downstream supported fisheries has been reviewed by Bilby and Likens (1980) and Schlosser (1982). Their work suggests that organic debris dams are a important component of small stream ecosystems and that their loss results in considerable seasonal and annual variation in the trophic structure and total biomass of aquatic ecosystems. By maintaining lateral and instream habitat complexity in association with channel stability we can best provide for the persistence of viable populations of these sensitive species over time (Karr and Freemark 1983; Karr and Dudly 1981; Gorman and Karr 1978).

The data collected to date suggest major changes in physical fish habitat have occurred in watersheds which have been entered for the purposes of timber harvest since the establishment of the National Forests, and support observations by Sedell and Everest (1990) of a long term decline in fish habitat quality throughout the Pacific Northwest. The unentered watersheds of the upper St. Joe were burned in the 1910 fire but are today stable and providing excellent fish habitat suggesting that the 1910 fire in and of itself is not the responsible for fish habitat conditions in Forest streams. Timber harvest and associated road construction appear to be the dominate land disturbing activities to which the observed shifts of habitat types and loss of pool volume and and depth can be attributed. The results of these data suggest that watershed restoration activities may have to take priority over harvest activities in watersheds where channel stability is the over-riding consideration relative to restoring the physical and biological integrety of the aquatic ecosystem and that changes in harvest techniques and road density and location may need to be incorporated into all future sales to maintain or improve channel stability and fish habitat.

Prepared by: Dave Cross, Forest Fisheries Program Manager

Date: March 1993

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Figure 1

St. Joe Watershed "A" type channels, percent by length

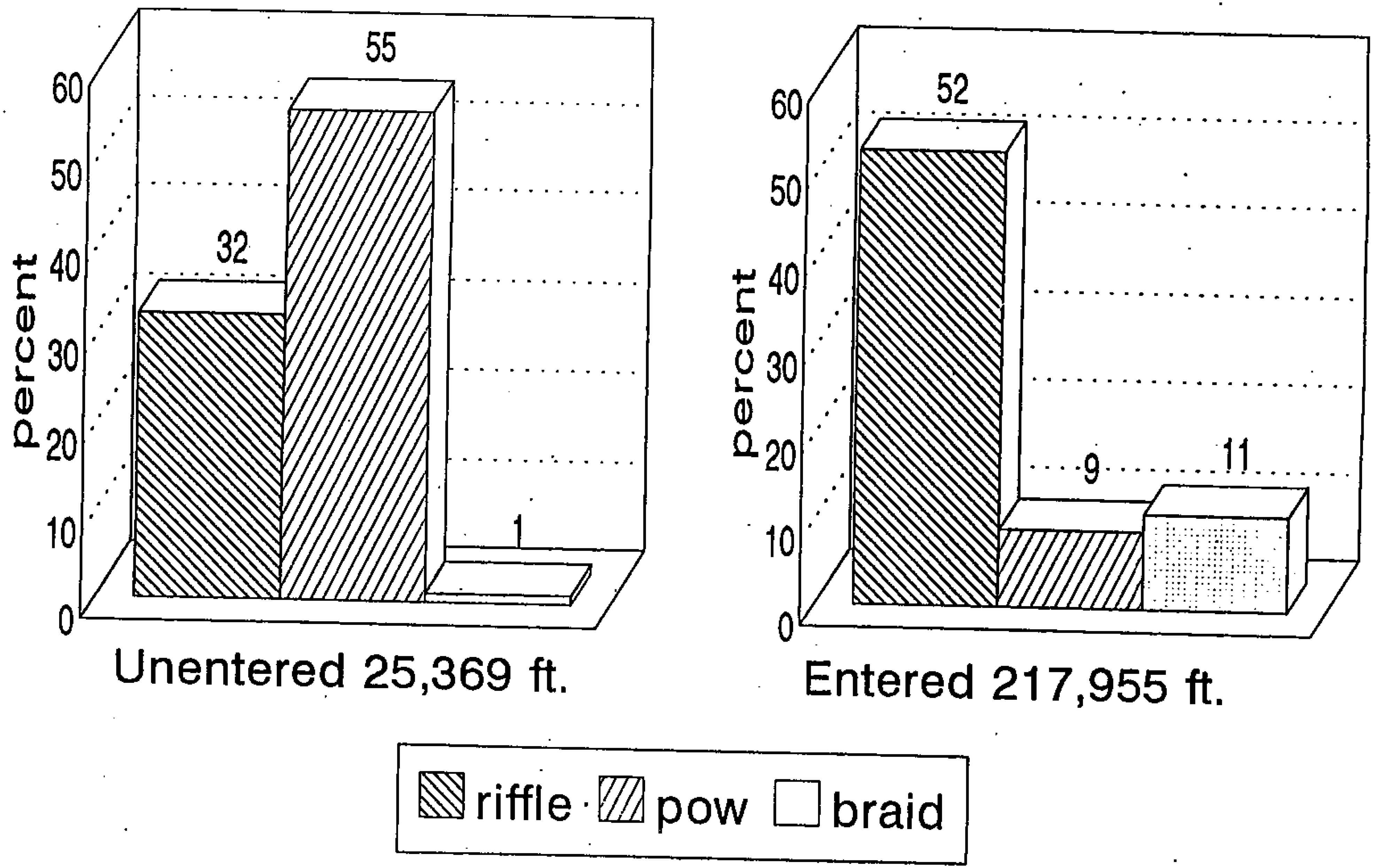
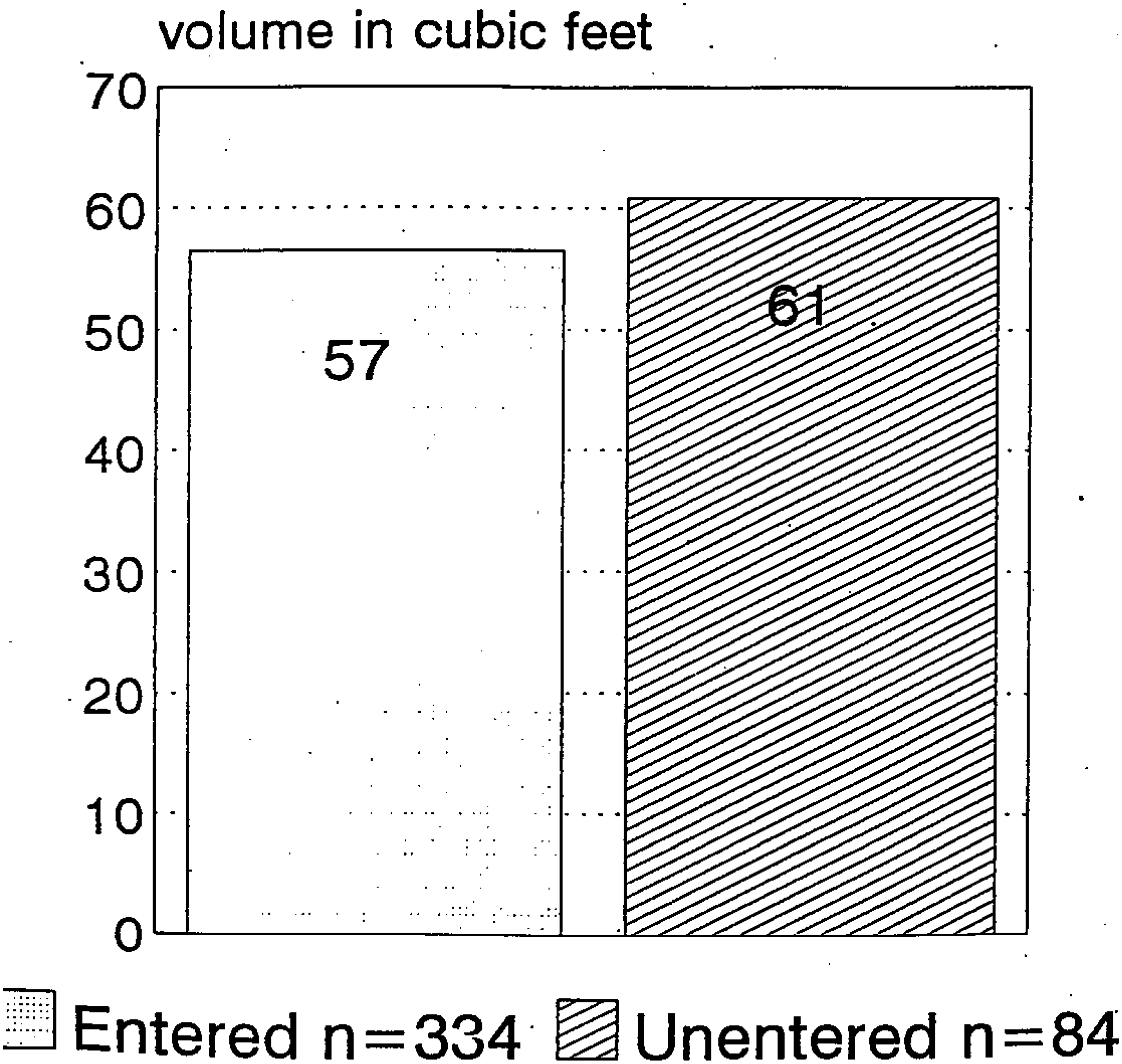


Figure 2

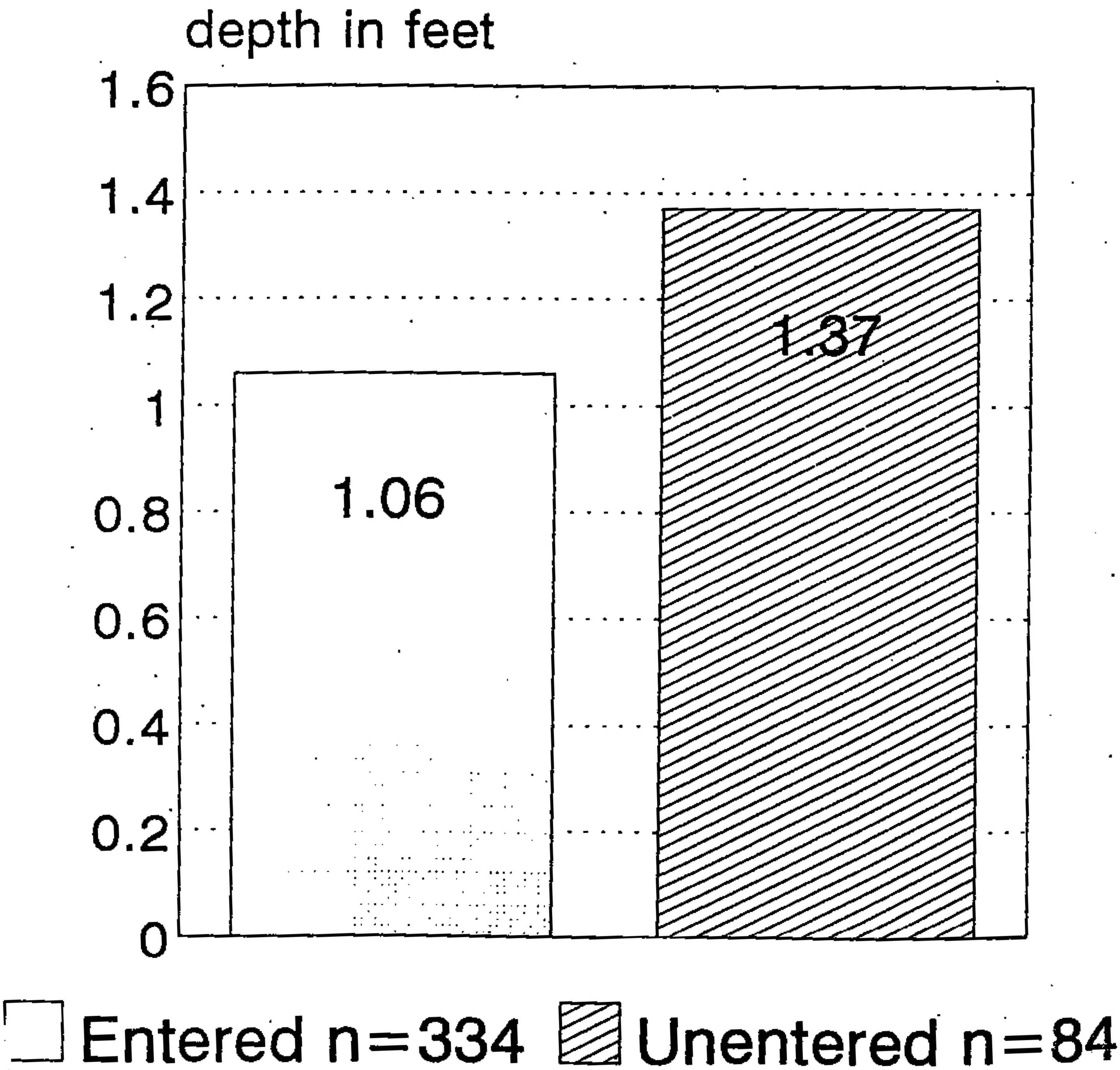
St.Joe River, First Order,"A" Type Channels
Residual Pool Volume



7% Difference in Volume

Figure 3

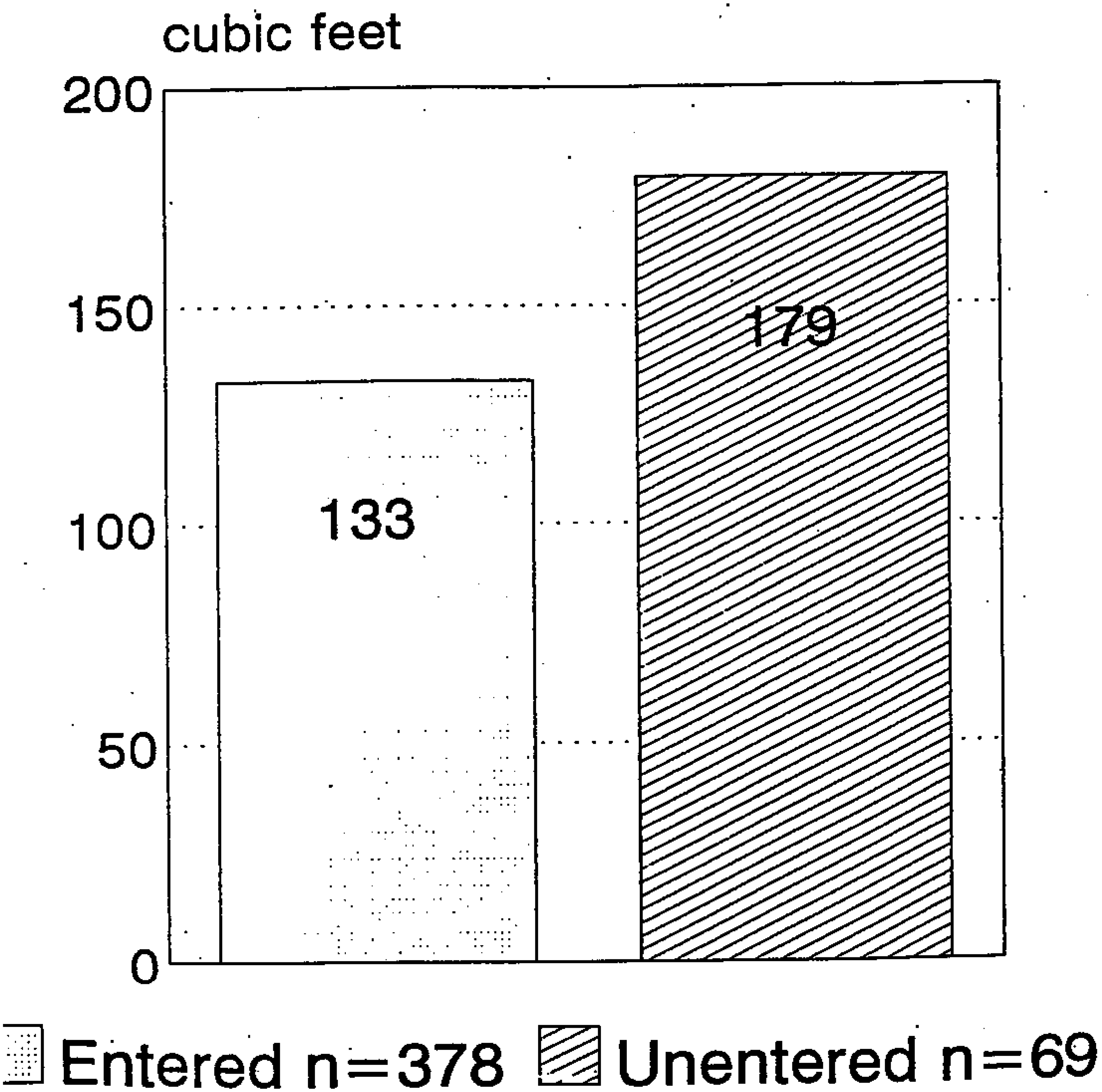
St. Joe River, First Order,"A" Type Channels
Maximum Residual Pool Depth



23% Difference in Depth

Figure 4

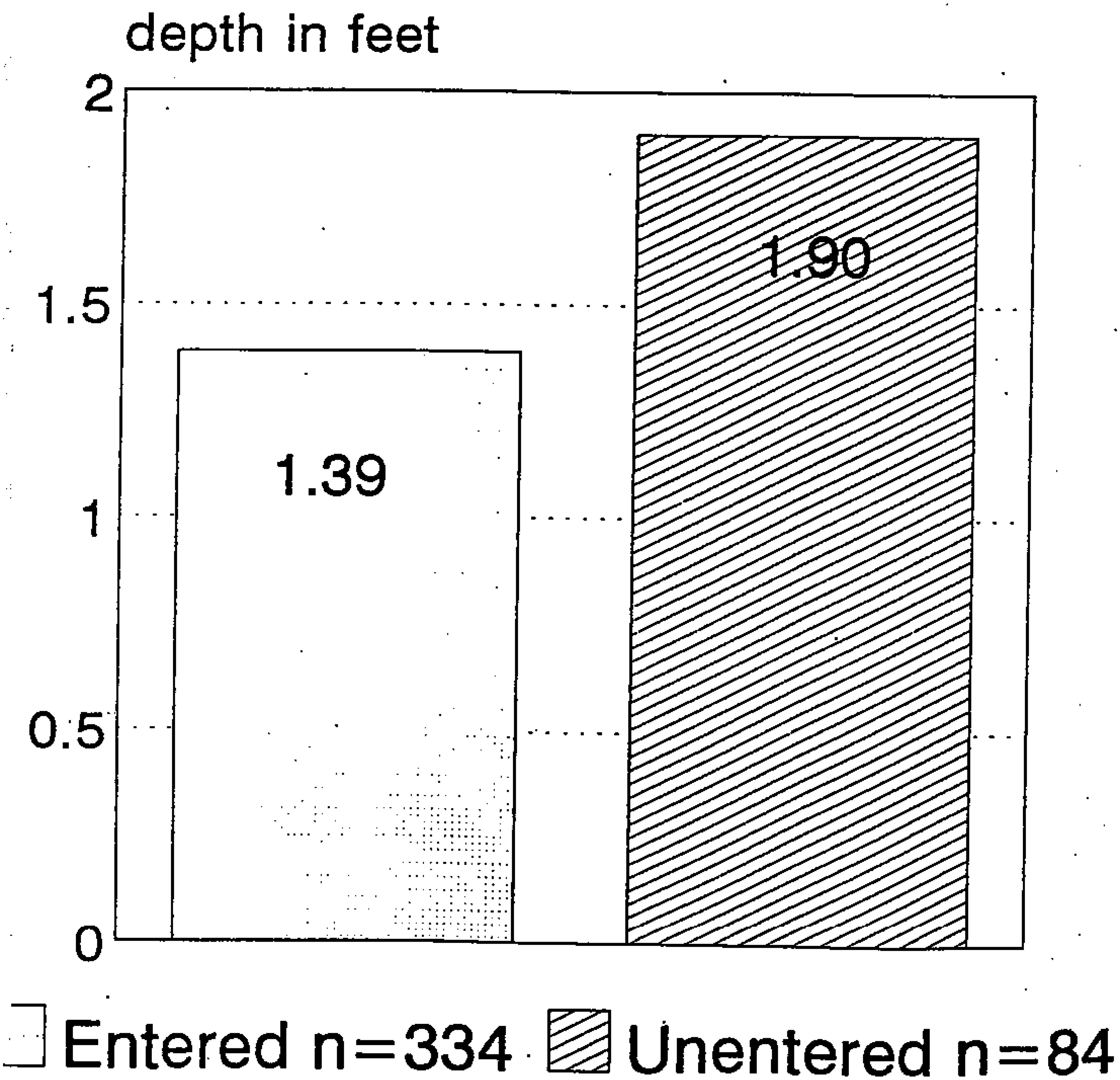
St.Joe River, Second Order,"A" Type Channels
Residual Pool Volume



26% Difference in Pool Volume

Figure 5

St.Joe River, First Order,"A" Type Channels
Maximum Residual Pool Depth



27% Difference in Depth

Figure 6

St. Joe Watershed,"B" type channels, percent by length

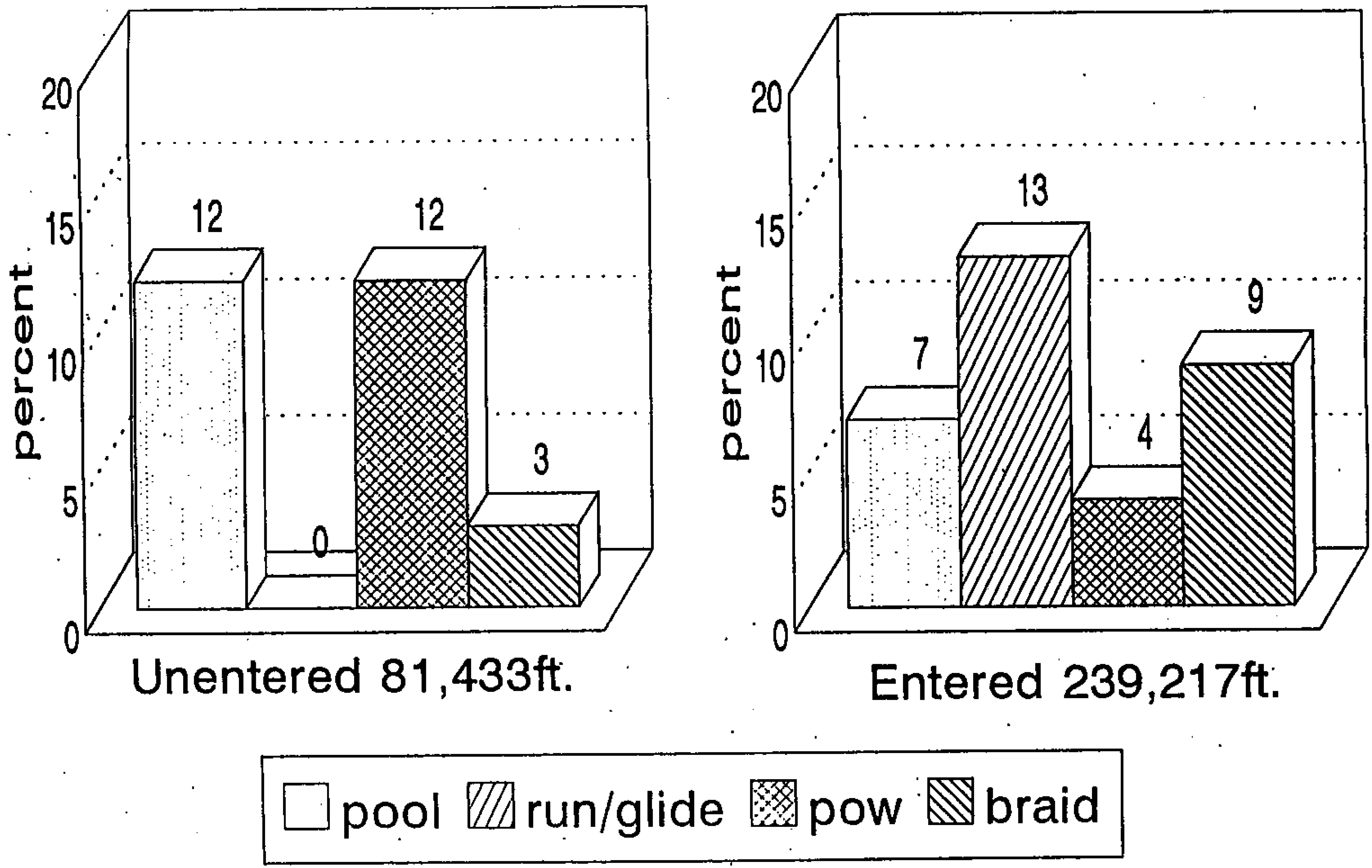
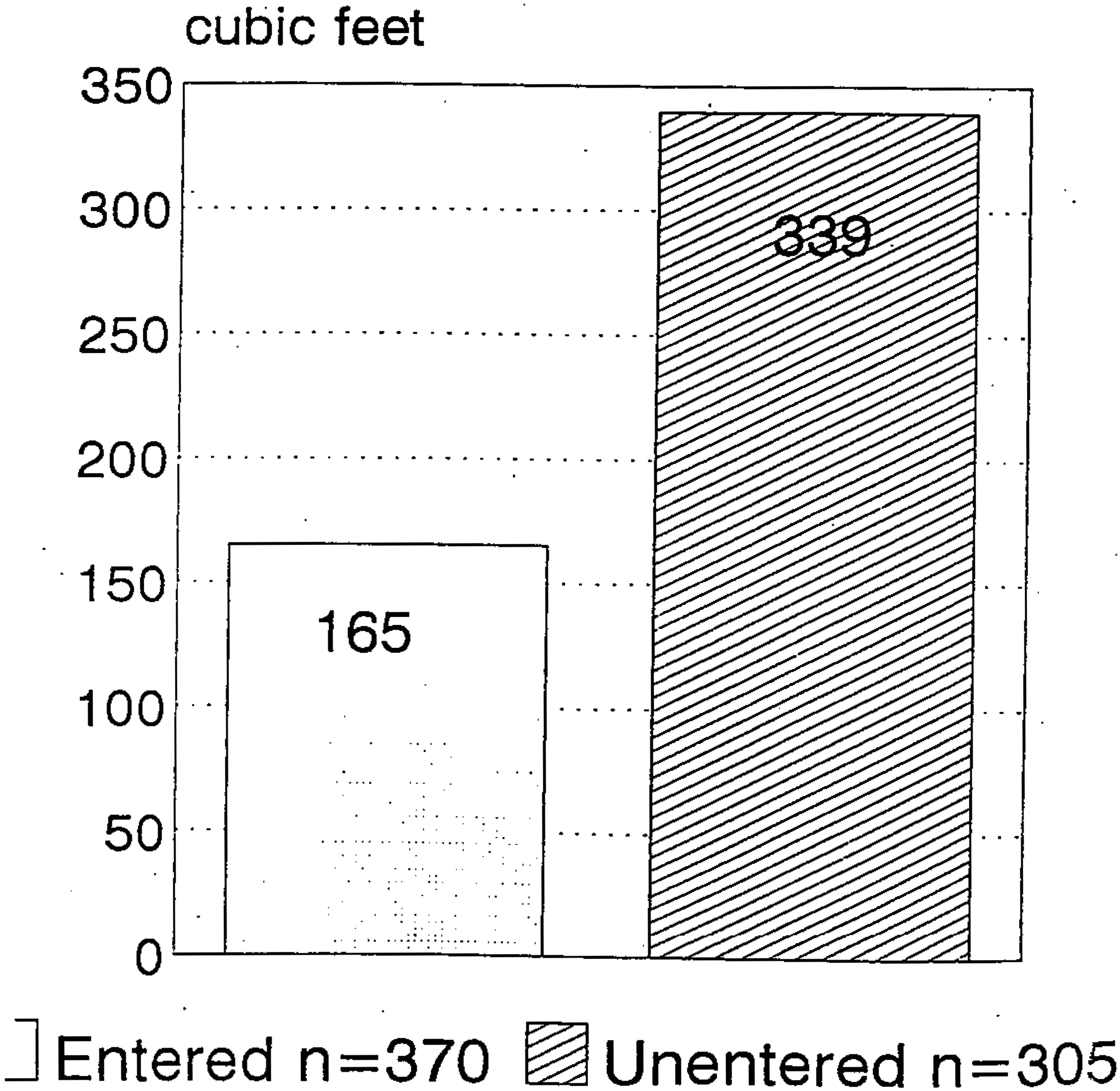


Figure 7

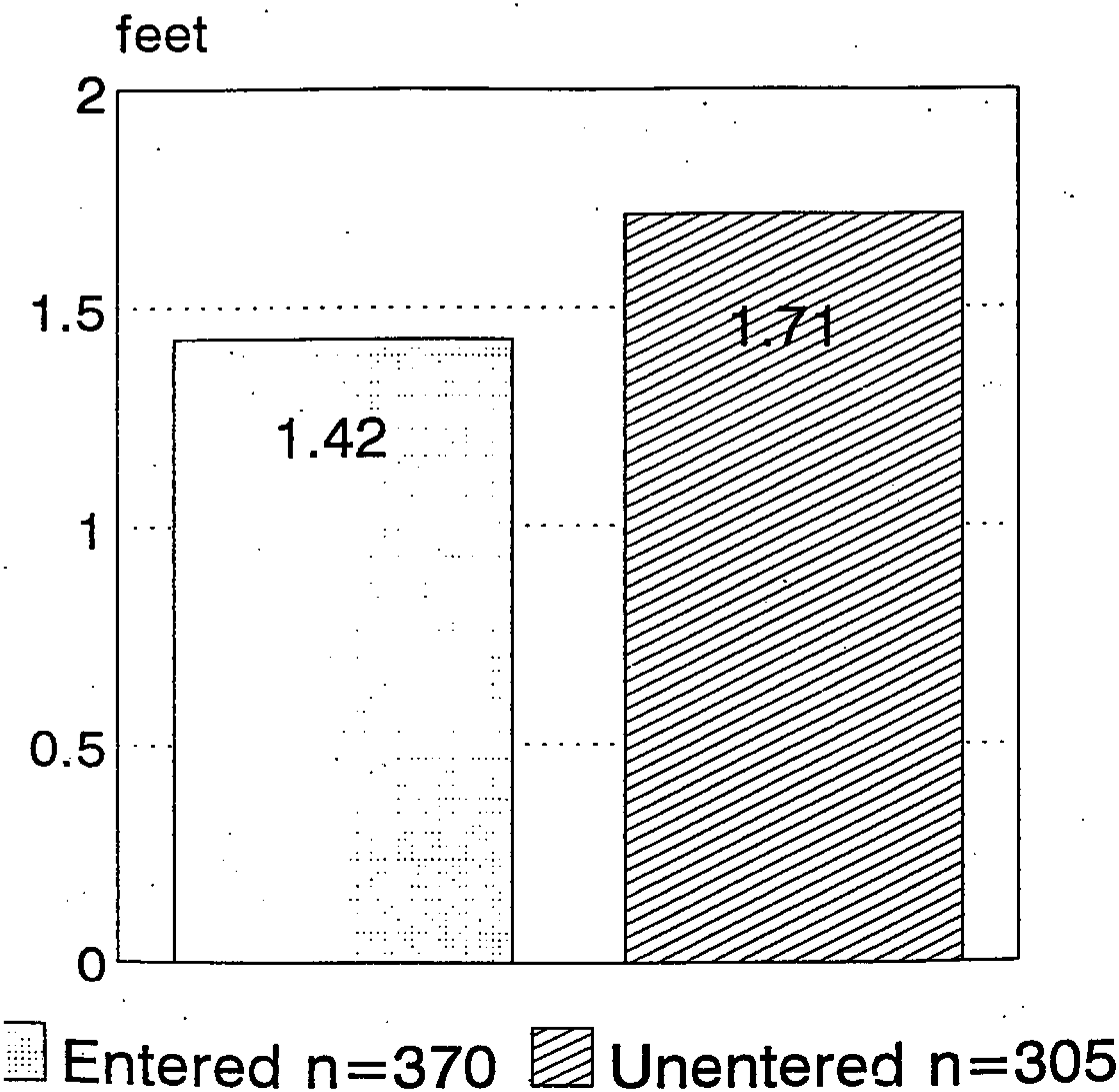
St. Joe River, Second Order,"B" Type Channels
Mn Residual Pool Volume



51% Difference in Pool Volume

Figure 8

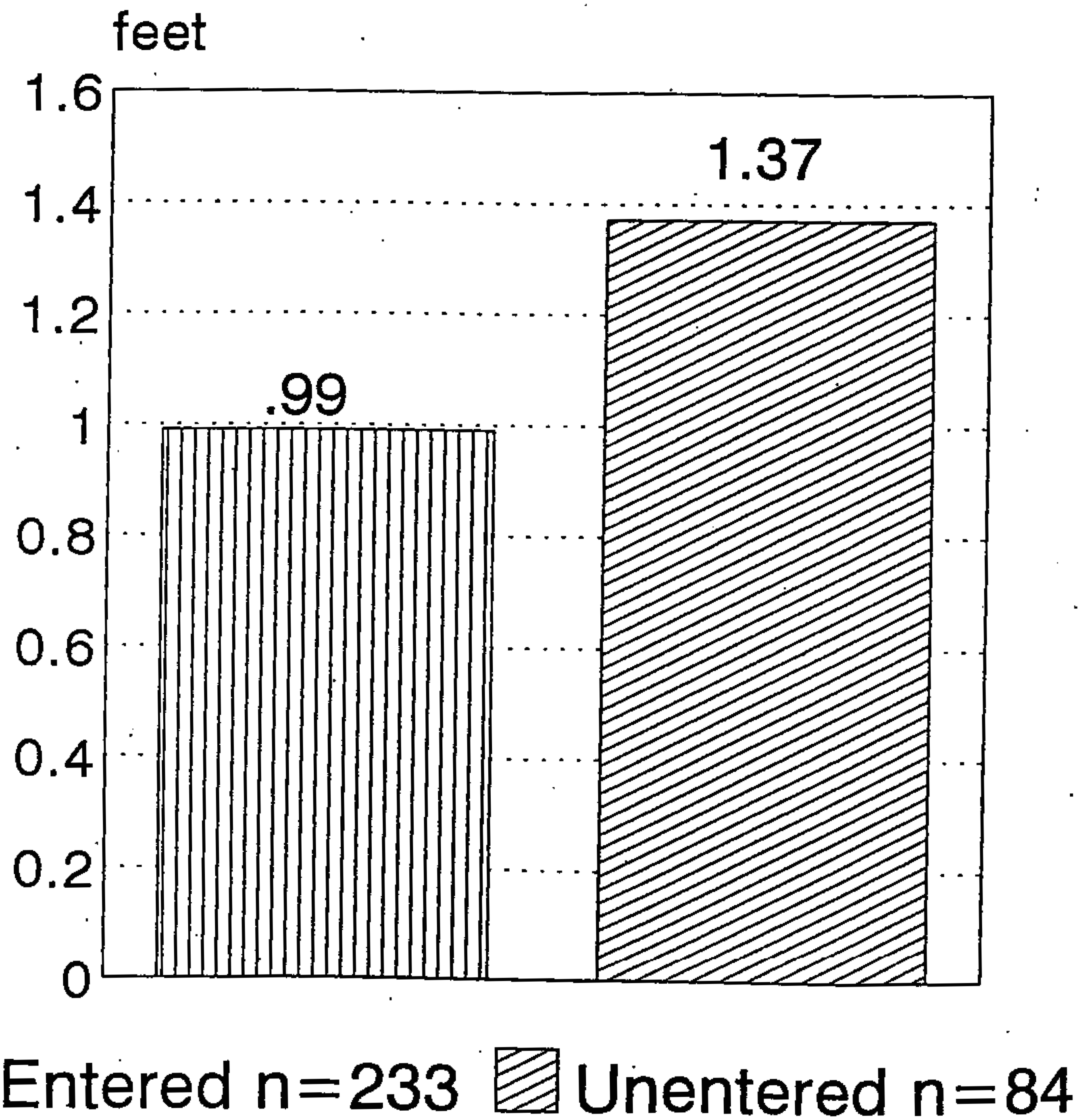
St. Joe River, Second Order,"B" Type Channels
Residual Pool Depth



17% Difference in Depth

Figure 9

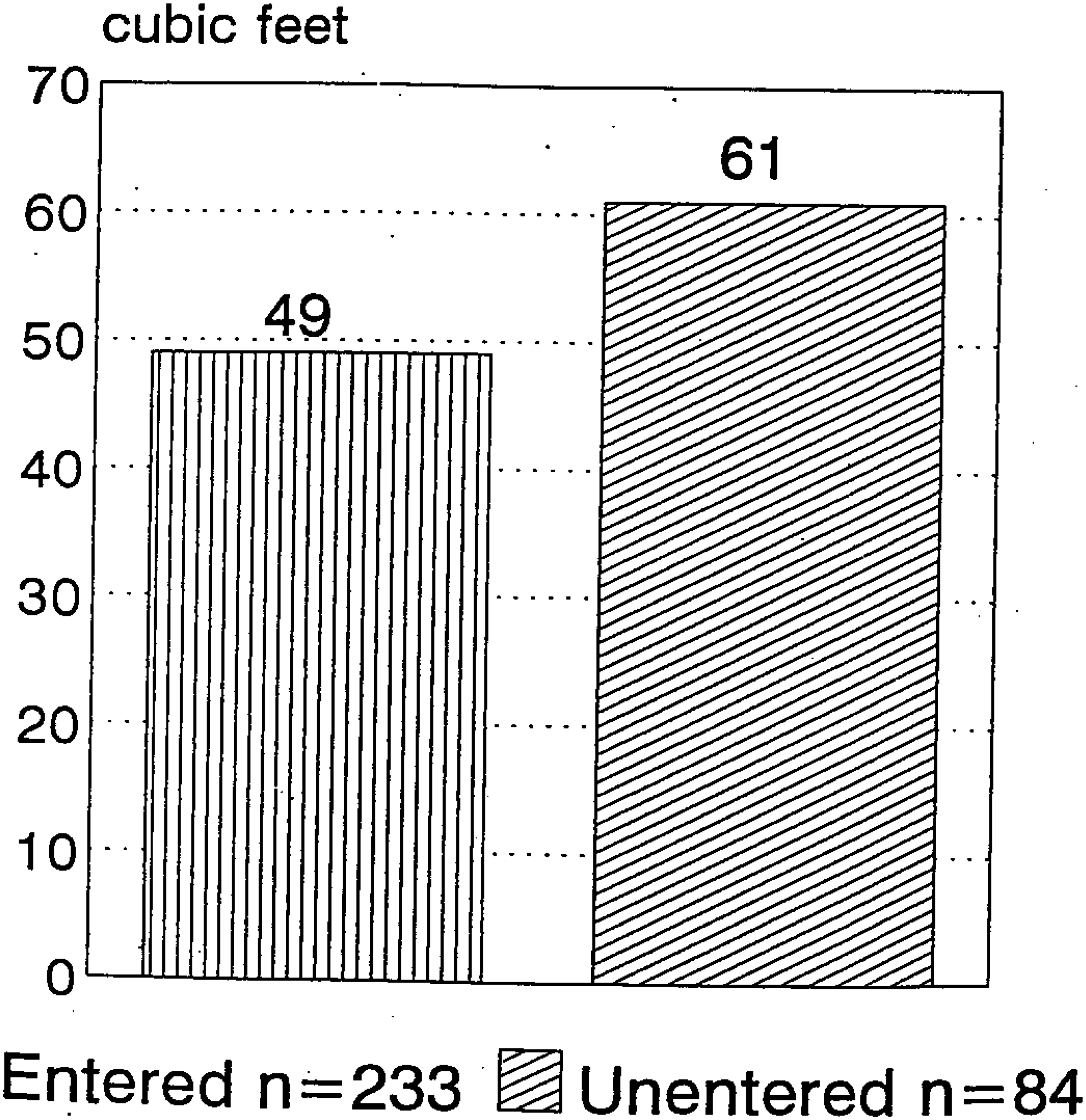
Coeur d'Alene, First Order,"A" Type Channels
Residual Pool Depth



28% Difference in Depth

Figure 10

Coeur d'Alene, First Order,"A" Type Channels
Mn Residual Pool Volume



19% Difference in Pool Volume

Figure 11,"B" type, Percent by length

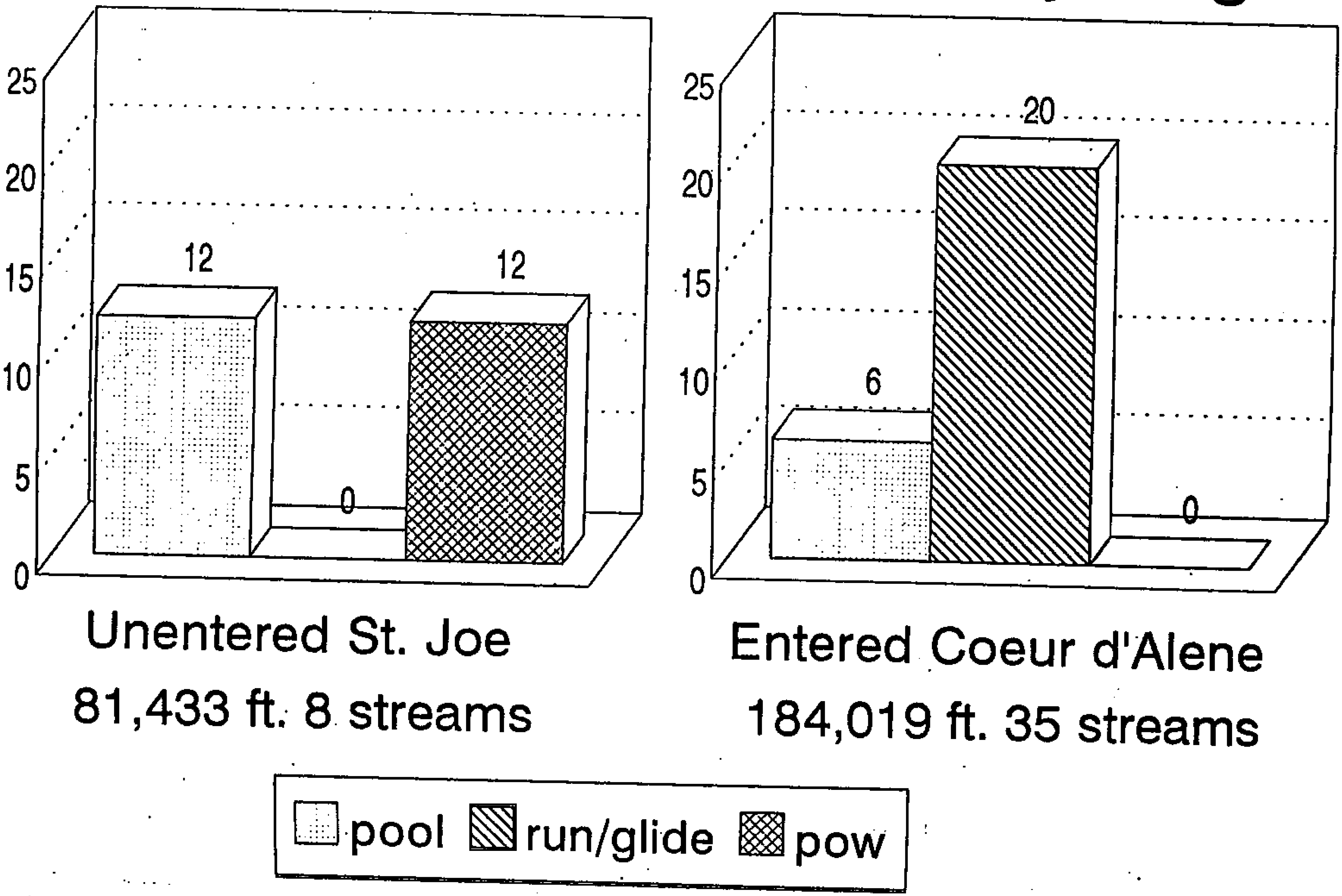
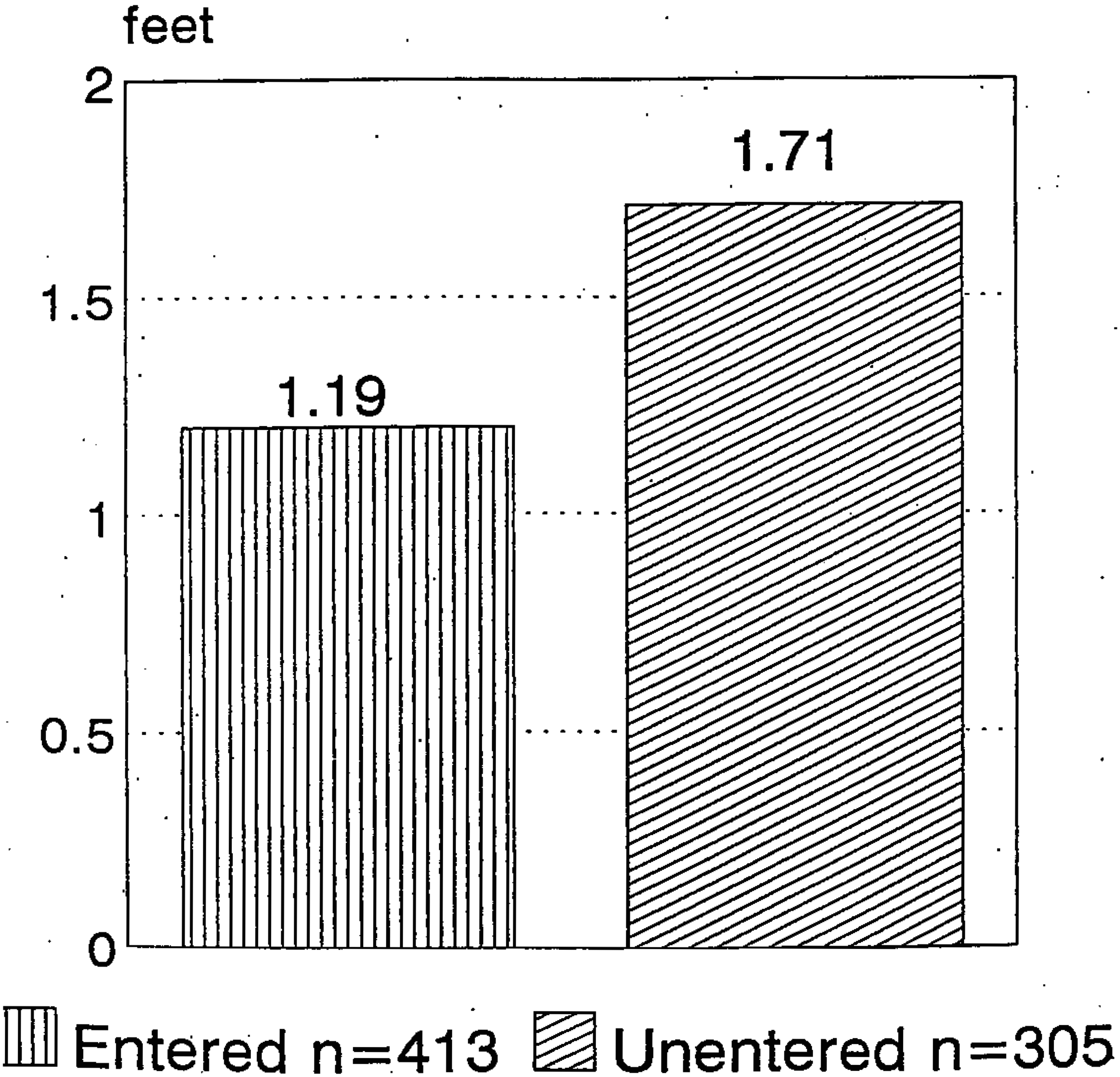


Figure 12

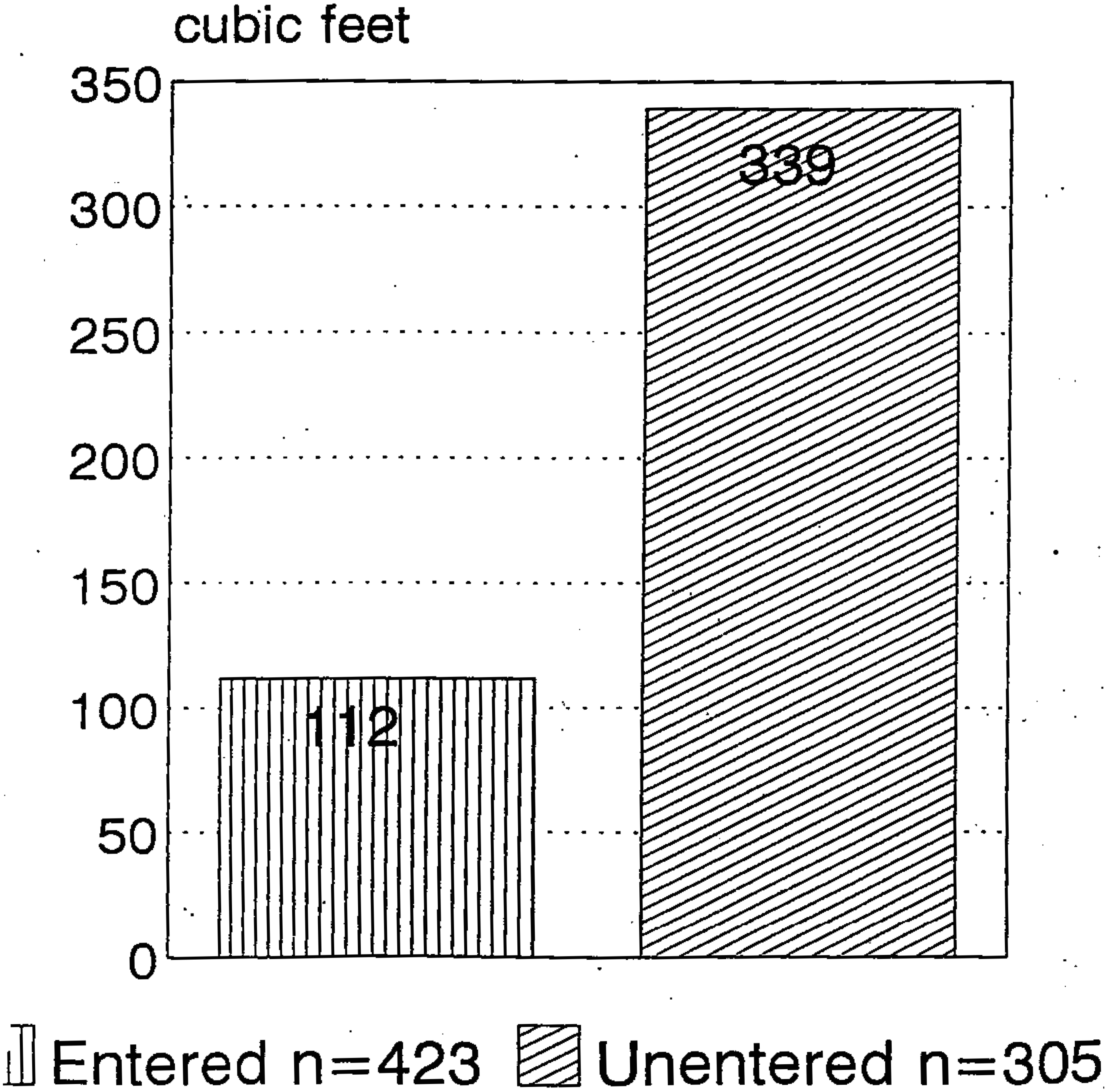
Coeur d'Alene, Second Order,"B" Type Channels
Residual Pool Depth



30% Difference in Depth

Figure 13

Coeur d'Alene, Second Order,"B" Type Channels
Mn Residual Pool Volume



67% Difference in Volume